Technical Efficiency in the Italian Machine Tool Industry: the effect of outsourcing, size, type of ownership and location*

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Abstract

Technical efficiency involves a firm's ability to avoid waste by producing as much output as input usage allows. After obtaining reliable measures of efficiency at the firm-level of analysis, empirical research helps us to identify those factors which influence variations of efficiency among similar economic units. The aim of this paper is to investigate the impact of factors which are assumed to account for the variability of firm's technical efficiency in a key Italian manufacturing industry, machine tools (MT). In particular, using an unbalanced panel database of 500 firms in the period from 1999-2007, I try to disentangle the effect of firms' vertical *structure* from the effect of its outsourcing *process*. Size shows a negative (even if non-linear) influence on the level of technical efficiency, while a more integrated structure of the firm is positively related to efficiency. Outsourcing is positively related to technical efficiency, while firms in industrial groups seem more efficient than independent firms. Firms located in industrial districts are more efficient than those located somewhere else. Finally a trade-off between efficiency and "flexibility" has been assessed in the post-estimation analysis.

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1 Introduction

Technical efficiency involves a firm's ability to avoid waste by producing as much output as input usage allows —output orientation— or by using as little input as output production allows —input orientation—[1]. Thus, technical efficiency is an indicator of firm performance, and empirical studies have shown that at different levels of disaggregation, some firms are efficient while others operate "below the frontier". After obtaining reliable measures of efficiency at the firm-level of analysis, empirical research help us to identify those factors which influence variations of efficiency among similar economic units[2].

The aim of this paper is to investigate the impact of factors[3] which account for the variability of firms' technical efficiency levels in the Italian machine tools (MT) industry, through a stochastic frontier analysis.

The study focuses on the MT industry since Italy is highly competitive in this sector, occupying the third position in export value and fourth in value of production in 2007[4]; moreover, this industry which is at the core of the country's industrial system, producing investment goods. Figure 1 and Figure 2 provide a brief overview on trends of production and export in the last decade. A look at these tables gives an idea about international

[1]Koopmans (1951) first defined the concept technical efficiency but remained the problem of how to measure it. Debreu (1951) and Shepard (1953) defined an output (input) oriented measure of efficiency, as the maximum equiproportional augment (decrement) of all outputs (inputs), taking the value of inputs (outputs) as constant. Farrell (1957) was the first to measure productive efficiency empirically: he showed how to define cost efficiency, and how to decompose cost efficiency into its technical and allocative components, providing an empirical application to U.S. agriculture by a linear programming techniques. Farrell's approach influenced pioneer works by Aigner and Chu (1968), Seitz (1971) and Afriat (1972) on deterministic production frontiers. These works can be considered as "forebears" of stochastic frontier approaches. Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977) proposed the stochastic frontier model, starting from the idea that deviations from the production frontier might not be fully under the control of the firm.

[2]Kumbhakar and Lovell (2000) write "The analysis of productive efficiency [...] should have, two components. The first is the estimation of a stochastic production (or cost or profit or other) frontier [...]. [t]he second component is to associate variation in producer performance with variation in the exogenous variables characterizing the environment in which production occurs".

[3]In the productivity and efficiency literature, these factors are usually indicated as "determinants" and we will adjust to this common practice. However, it should be noted that, the employed econometric approach (as in many other studies of the field) would advise against calling them "causes" but just significant related variables.

[4]For a detailed report on the industry evolution in terms of value of production, exports and imports see Ucimu (2007a) and Ucimu (2007b) .

leadership at the country-level(Japan and Germany), and recent rise (China) and fall (US) of other countries. Italian MT industry developed as a "true" industry in Italy following the second world war. Nowadays it is characterized by experienced producers and consumers, pervasiveness of technological knowledge, high sunk costs (e.g. cast iron basement), stability among leaders in the ranking position (see Rolfo, 1998; Rolfo and Calabrese, 2006). The industry is also typical of Italian production units: small and medium enterprises, mainly localized in few areas and frequently owned and controlled by families. By concentrating on a specific industry in a single country, it is possible to control for environmental factors common to all firms: i.e., institutional factors and innovation patterns.

This paper analyzes five factors affecting efficiency: the firm's vertical *structure*; the outsourcing *process* conducted by the firm; size, type of ownership, and district location. A major feature of the paper is the simultaneous adoption of two measures in order to disentangle the effect of firm's vertical structure from that of outsourcing. Firm's vertical structure is assessed by a variable in levels, while the outsourcing process by a variable in differences.

The MT industry seems a very interesting case study. As a matter of fact, the industry has experienced, starting from the sixties different models of firms' vertical structure. Different phases of production have been alternatively outsourced or made in-house. Moreover, the choice of these exogenous factors is driven by the interest in relationships which are frequently debated in Italy: differences in term of efficiency between small and medium enterprises (SMEs) on the one hand and large enterprises (LEs) on the other, the performance of family-owned firms versus subsidiaries of national and international groups, and the role of industrial districts in enhancing firms' efficiency.

The paper is structured as follows. Section 2 provides the basic framework of the analysis and the hypotheses that will be tested. Section 3 describes the employed data. Section 4 discusses the results of the analysis. Section 5 provide conclusions and suggestions for further research.

2 Basic framework and hypotheses

2.1 Determinants of technical efficiency and hypotheses

No compact theoretical model on the identification of determinants of technical efficiency exists (Lovell, 1993), and I draw on past studies that have empirically identified determinants, especially the pioneering work by Caves and Barton (1990) on the US manufacturing industry, and that of Caves and Bailey (1992), which examines the issue in a global context.

These studies identify variables that are neither inputs nor outputs, but nevertheless affect the production process. Two main groups of determinants can be identified: factors *external* to the firm and factors *internal* to the firm[5].

Utilizing this classification, some general and preliminary observations can be made. The influence of such determinants on the existence of different levels of technical efficiency in the same industry can be consistent with a neoclassical economic equilibrium only if one of the two following conditions —or both of them— occur[6](see Pozzana and Zaninotto, 1989):

- Lack of observation: There are some factors which are not usually taken into account in the estimation of the production function, because they are external to the firm (e.g., all characteristics of the production "environment" in which the firm operates) and they are simply not observed. This lack of observation can result in apparently different firms' levels of technical efficiency, even within a highly —from a technical point of view— homogeneous industry.
- Lack of perfect competition: If perfect competition does not hold in an industry, leaving room to oligopolies or monopolistic competition[7], it is plausible to find different levels of technical efficiency among firms. For example, if the extent of structural product differentiation in an industry is high, this product heterogeneity will be reflected in the higher variability of technical efficiency. Firms would be characterized by different levels of efficiency for qualitative differences in the outputs they offer.

These motivations makes the detection — and the adoption by some firms— of apparently inferior techniques effective.

The introduction of exogenous variables in stochastic frontier models have generated a huge debate, capturing the attention of scholars. Here, I can briefly remind the two main issues (see Kumbhakar and Lovell, 2000, Chap.7, among others):

[5]Factors external to the firm are: industry characteristics (degree of concentration, stage in the industry life cycle); region and district location (to account for agglomeration and spillover effects); capital market constraints; market disturbances (expansions, contractions). Factors internal to the firm relate to size, outsourcing and offshoring, employees skill composition; innovation and R&D investments; international status (extent of exports, foreign direct investments); advertising investments; type of ownership (public versus private, national versus foreign, single-unit versus groups).

[6]Greene (1993), p.70 writes: "Strictly speaking, an orthodox reading of microeconomics rules out Farrell's interpretation. A competitive market in equilibrium would not tolerate inefficiency the sort considered here."

[7]Monopolistic competition is a market form similar to perfect competition, in which there are heterogeneous products, and it involves a great deal of non-price competition. In this market form, a company can raise its prices —because of brand loyalty— without losing all of its customers.

1. theoretical: the decision to include the exogenous variables as parameters of the frontier function (influencing the "shape" of the frontier) or as determinants of the inefficiency term (influencing the "distance" from the frontier);

2. methodological: in the case in which the exogenous factors are assumed to affect levels of efficiency, the way in which their effects can be computed have been debated; the choice is basically done between 1-step and 2-steps procedures;

If the first issue should be addressed by careful considerations driven by economic theory, the second one has been studied extensively by econometricians. However the preference for one-step estimations have been deeply justified by Wang and Schmidt (2002).

In this study, the chosen formulation regards exogenous variables affecting the (in)efficiency term. That is because all considered factors affect more the *way* in which the production process is conducted (distance to production function frontier), than the *type* of production process that is conducted (production function frontier)[8].

The model has been estimated through a stochastic production frontier model with heteroskedasticity, using a one-step procedure. The following sections describe the five factors which have been implemented as explanatory variables for technical efficiency levels.

Outsourcing and the vertical structure of the firm

Starting from the sixties, the Italian MT industry has faced different configurations in the typical vertical structure (see Rolfo, 1998, 2000). In the fifties alongside firms specialized in market-oriented machine tool manufacturing, the most important mechanical engineering firms produced their own MT in-house (from foundry to finished products) thus the model was that of vertical integrated firms. Just in the sixties, a significant increase in internal demand stimulated the growth of an independent MT industry. The seventies were characterized by the "small-firm" model, with a consequent vertical dis-integration of firms. Especially electronic and computer components were outsourced (seldom design too). Even with slight changes over time, this low level of vertical integration has remained stable for the majority of Italian MT firms till today[9]. Nowadays, machine tool builders basically leave outside the production of standardized components (mainly electronics) because of small scale and, sometimes, also the desing of machines and software planning

[8]Factors which could affect the shape of the production function as well as the distances to it are the vertical structure of the firm and the outsourcing process. Nevertheless, outsourcing has been implemented as determinant of technical efficiency in several empirical studies (see Taymaz, 2005, among others). Future research should take into account this possibility.

[9]Italian manufacturing firms have traditionally showed lower levels of vertical integration than their counterparts in other European countries like Germany and UK (see Arrighetti, 1999).

have been left outside of the firm, because of lack of skilled workers. The vertical position of the firm along the production chain seems a key dimension in this industry, which has not only consequences regarding efficiency in production, but also regarding the control of knowledge, and the innovation process conducted by the firm. As an example, Poledrini (2008) finds, through some case studies, that Italian MT firms are loosing the knowledge of the key parts of the machine in favor of their suppliers (technological know-how), i.e. they are basically loosing the control of the vertical chain, because of a shrinking of knowledge.

Analyzing the issue on a global context Grossman and Helpman (2005) emphasize that firms seem to be outsourcing an expanding set of activities. Outsourcing refers to the tendency of the firm to allocate to other firms some of its production and non-production activities. It captures the contraction —over time— of the vertical structure of the firm along its production chain: thus, it is not simply symmetric to vertical integration, because vertical integration is a measure in "levels", while outsourcing is a "dynamic" process.

This distinction has seldom been implemented in empirical/applied works. We can hypothize that even signs of relationships with efficiency could be different, if we look at the two phenomena separatedly. That seems justified also by economic theories, which I briefly summarize below.

- A basic rationale to implement outsourcing is a cost-savings' strategy; outsourcing is expected to imply cost savings relative to internal production or internal services functions. Keeping this in mind, it is reasonable to expect a positive relatioship between outsourcing and efficiency (see Hashmati, 2003).

- The vertical structure of the firm and the decision by the same to be vertically integrated or not has been largely studied in the transaction costs framework (Williamson, 1971) and in the property rights literature (Grossman and Hart, 1986; Hart and Moore, 1990). The transaction cost framework predicts firm's decision to be vertically integrated if asset specificity is high, search efforts to find other buyers/suppliers are high, and the frequency of the relationship is high. The property rights approach would predict inefficient under-investment levels under contract incompletenes by both parts of the relationship, thus suggesting for vertical integration by the part that mostly contributes to the value of the relationship. Noting that Italian MT industry has always been characterized by close producers-users relationship and the tendency by producers to model final products to users' needs, thus making specific invesments in the relationship, the effect of more vertical integrated structure on firms' performance is expected to be positive.

- Recently, also the international trade literature regarding offshoring have dealt with the vertical structure of the firm, fundamentally basing its results on hypotheses about fixed costs. For example, Antràs and Helpman (2004) presuppose that fixed costs of integration are higher than fixed costs of dis-integration; they show that productivity ranking influences firm's choices: more productive firms should decide to be vertically integrated abroad, while less productive firms to be dis-integrated at home. An interesting application of this framework to the Italian manufacturing has been conducted by Federico (2009). Following this literature, more vertically integrated structure are expected to be associated with higher levels of efficiency.

In this paper, I try to distinguish between the outsourcing process and the vertical structure of the firm, using two different measures[10]. I expect to find a positive relationship between levels of outsourcing and efficiency, because it is reasonable to think that firms, starting from a given vertical structure, will sub-contract those activities in which they are less productive.

Hypothesis 1.1-A positive relationship is expected between outsourcing and levels of firm technical efficiency.

However, given the above theories regarding the vertical structure of the firm (i.e. transaction costs framework, property rights approach, recent international trade models), and the nature of MT industry, the following hypothesis holds.

Hypothesis 1.2-A positive relationship is expected between higher levels of vertical integration (more integrated structures) and firm technical efficiency.

Size of the firm

Wengel and Shapira (2004) observe a dualistic structure in the Italian MT industry, with many small specialized enterprises and few large companies. Customization of machines led Italian MT firms (especially small ones) to characterize their production by low levels of standardization. Rolfo (1993) says that Italian MT firms operate below the minimum optimal scale. This fact carries other issues: the first one is a relatively (to other countries' MT industry) low presence of Italian subsidiaries in foreign countries, because their average size is inadequate to survive in the global market, especially for implementing delocalization. The second one relates to the lack of possibility to perform those activities where scale is important (see Rolfo, 2000, e.g. marketing and research).

The relationship between size and efficiency has been largely debated in the empirical literature[11], but it is still not a clearcut: see Caves and Barton (1990) for an investigation in US manufacturing; Gumbau and Maudos (2002), Diaz and Sanchez (2008), Taymaz (2005) have conducted empirical investigations on Spanish and Turkish manufacturing;

[10] Unfortunately, available data do not permit to distinguish between outsourcing at home and abroad.

[11] The theme has also been deeply studied in the empirical literature regarding agricultural production.

Badunenko, Fritsch, and Stephan (2008) analyze the relationship for German manufacturing. The contrasting evidence indicates to conduct single-industry studies in order to clearly monitor the relation between size and efficiency. There are several considerations that could justify the observation of a variability of technical efficiency scores across plants of different scales:

- The first one deals with the industry evolution selection process (Jovanovic, 1982). In a model of industry evolution, efficient firms should grow, while inefficient firms should stagnate, finally exiting from the market. This fact should make the researcher observe a positive relationship between size and efficiency at the firm level.
- Second, LEs are able to employ higher quality inputs with respect to SMEs. Moreover, small-scale activities attract people with a high variance of entrepreneurial skills, while managers of larger units must display at least a threshold of competence (Kumar, 2003).

These first two motivations would bring us to hypothesize a positive relationship between firm size and efficiency:

Hypothesis 2.1-A positive relationship is expected between firm's size and technical efficiency.

However, the MT industry has traditionally showed cycles in the trend of demand. Looking at Italian data in Figure 1, which refers to the last decade, it is possible to appreciate that value of production (which can be assumed as a proxy for demand), has risen in the period 1999-2000, then it fell down in the period 2001-2004, finally re-starting to increase from 2005 to 2007.

Given this feature of the industry under analysis, the following motive holds.

- SMEs could exploit their advantage of managing labor input in uncertainty environemts (flexibility): this is the case of cyclical industries where the demand trend is characterized by peaks and gorges.

This motivation lead us to verify the following hypothesis:

Hypothesis 2.2-Differences in efficiency between LEs and SMEs could be balanced by a "flexibity-advantage" of the smaller ones, and this should appear more evident in periods of contraction of demand.

Finally the possibility of different production functions (and not simply input combinations) for SMEs and LEs can be effective. In this case the observed differences in technical efficiency could due to a wrong common speficication of the production technology to both SMEs and LEs (see the employed switching regression models and metafrontier model implemented by Yang and Chen (2007).)

However, we not assume different production functions for SMEs and LEs.

Type of ownership

The eighties were characterised by a structural strengthening of the industry via external growth, i.e. the formation of small industrial groups in order to retake control over the filière (Rolfo, 1993). This tendency, which slowed down in the first half of the nineties, re-started with strenght in the second part of the nineties, becoming the way in which MT builders tried to keep the control of the production process. From the second half of the nineties several mergers has happened in the broader mechanical engineering industry (Rolfo and Calabrese, 2006). This has happened for different reasons: the first is to cope with risk (especially small firms, which have developed small industrial groups), the second one is trying to exploit market and production complementaries, through groups that work in more divisions of mechanical industry (especially large enterprises). This tendency makes the existence of different ownership structure in the industry and their relationship with efficiency interesting to be studied.

Conflicts of interests inside firms mostly relate to conflicts between ownership (shareholders) and control (management). Members of the two groups have an incentive to increase the benefits that they appropriate to themselves if a surplus is available to participants. This ex-post opportunism is a source of technical inefficiency (Coppola, Maietta, and Pascucci, 2008). It is possible to make the reasonable assumption that these conflicts are less severe in independent firms where ownership and control mostly overlap, making possible to avoid free rider problems of corporate control (Shleifer and Vishny, 1986)[12].

In the Italian MT industry (as in the whole Italian industry), however, there are small groups which are typically owned by families, consequently not being so different in ownership concentration from independent firms, and controlled by managers who are members of the same family. Thus, belonging to an industrial group should be less associated (with respect to other countries) to conflicts between management and ownership. Moreover, available data do not permit to separate subsidiaries of multinational enterprises from subsidiaries of national groups, and the empirical literature (Bottasso and Sembenelli, 2004; Castellani and Zanfei, 2006) has showed that subsidiares of multinational are more efficient than independent firms. Giving these considerations, the following hypothesis can be stated.

Hypothesis 3- A positive relationship is expected between groups'affiliation and technical efficiency.

[12]However, a negative relationship could be the case, if concentrated ownership led to the extraction of inefficient private benefits by controlling shareholders at the expense of minority shareholders (Shleifer and Vishny, 1997)

District location

The information on firm's location into an industrial district should capture the following positive externalities: agglomeration effects, exchange of information among contiguous firms, frequency of interactions. These effects are not usually taken into account in a production function specification. Fabiani, Pellegrini, Romagnano, and Signorini (1998) find positive effect of district location on efficiency of a sample of Italian manufacturing firms in the period from 1982-1995. Becchetti, d. Panizza, and Oropallo (2008) show that firms localized in districts show higher value added per employe and higher export intensity.

Hypothesis 4- Firms located into an industrial district are expected to be more efficient than firms located somewhere else.

2.2 Estimation of technical efficiency: a stochastic production frontier model

The basic model follows Wang (2003). Assuming that a vector $\widetilde{\boldsymbol{x_i}}$ of N inputs is available to I firms $(i = 1, \ldots, I)$ to produce a single output y_i, and that firms are observed for $t \leq T$ periods $(t = 1, \ldots, T)$, the stochastic production frontier model can be written as:

$$y_{it} = f\left(\widetilde{\boldsymbol{x_{it}}}; \boldsymbol{\beta}\right) \cdot exp\left\{\epsilon_{it}\right\}, \tag{1}$$

where y_{it} is the scalar output produced by firm i in time t, $\widetilde{\boldsymbol{x_{it}}}$ is the vector of N inputs used by producer i in time t, $f\left(\widetilde{\boldsymbol{x_{it}}}; \boldsymbol{\beta}\right)$ is the production function frontier, $\boldsymbol{\beta}$ is a vector of technology parameters to be estimated, and ϵ_{it} the composed-error term. In the log-linear form, the stochastic frontier model can be re-written and specified in the following way:

$$lny_{it} = lnf\left(\widetilde{\boldsymbol{x_{it}}}; \boldsymbol{\beta}\right) + \epsilon_{it} \tag{2}$$

$$\epsilon_{it} = v_{it} + \iota_j + \tau_t - u_{it} \tag{3}$$

$$v_{it} \sim iid\, N\left(0, \sigma_v(\boldsymbol{z_{1it}}, \delta)^2\right) \tag{4}$$

$$u_{it} \sim Exponential\left(\eta\left(\boldsymbol{z_{2it}}, \gamma\right)\right) \tag{5}$$

If

$$\boldsymbol{x_{it}} = \left[1, \widetilde{\boldsymbol{x_{it}}}, \iota_j, \tau_t\right],$$

equations 2 and 3 can be rewritten as:

$$lny_{it} = lnf\left(\boldsymbol{x_{it}}; \boldsymbol{\beta}\right) + v_{it} - u_{it}.$$

Equations 2 to 5 tell that level of output y_{it} is a function of inputs $\widetilde{\boldsymbol{x_{it}}}$ and a composed-error term ϵ_{it}, which consists of (a) a white noise component v_{it}, which accounts for random shocks that are not under the control of firms, (b) industry-specific effects ι_j which account for observed heterogeneity[13], (c) time-specific effects τ_t, and the technical inefficiency component u_{it}, which indicates the departure of the actual level of production from the maximum attainable level. The v_{it} component is assumed to have a normal distribution, while the u_{it} component is assumed to be independently distributed of the v_{it}, and to be distributed as an exponential with η(eta) parameter. In particular, the probability density function of u_{it} is:

$$f\left(u_{it}\right) = \frac{1}{\eta_{it}} \cdot exp\left\{\frac{-u_{it}}{\eta_{it}}\right\}, \tag{6}$$

with $E\left(u_{it}\right) = \eta_{it}$ and $Var\left(u_{it}\right) = \eta_{it}^2$. Both error components are assumed to be heteroskedastic: in this framework, their variances σ_{vit}^2 and η_{it}^2 are allowed to vary across production units, as functions of vectors of the selected exogenous variables, respectively $\boldsymbol{z_{1it}}$ and $\boldsymbol{z_{2it}}$[14].

These variables (which are not inputs) influence the efficiency of the production process, and they can be beyond or under the control of the production units.

2.3 Model specification

I use a translog specification in order to estimate the production function frontier:

$$lny_{it} = \beta_0 + \tau_t + \iota_j + \sum_n \beta_n lnx_{nit} + \frac{1}{2}\sum_n \sum_p \beta_{np} lnx_{nit} lnx_{pit} + v_{it} - u_{it}{}^{15},$$

where lny_{it} is log of output of firm i in time t; lnx_{nit} are inputs in logs, where $n, p = (capital_{it}, labor_{it}, intermediateinputs_{it})$; τ_t are year dummies and ι_j are sub-industries dummies. Each one of $\tau_t s$ and $\iota_j s$ have been purged to avoid collinearity.

The multiplicative heteroskedastic functional form has been implemented to model variances of the inefficiency term and of noise (see Laureti, 2008):

$$\eta_{it}^2 = exp\left(c_2 + \boldsymbol{z_{2it}}\gamma\right), \tag{7}$$

[13] See Greene (2008), paragraph 2.6.

[14] Wang and Schmidt (2002) note that $\boldsymbol{x_{it}}$ and $\boldsymbol{z_{it}}$ may overlap. But the model specify a distribution of y conditional on x and z: thus, x and z are treated as "fixed", i.e. there is no feedback from y to x and z.

[15] The symmetry condition has been imposed to the translog function: $\beta_{np} = \beta_{pn}, p \neq n$.

where

$$\boldsymbol{z_{2it}} = (outsourcing_{it}, vertical(dis)integration_{it}, size_{it}, ownership_i, district_i)\,,$$

and

$$\sigma^2_{vit} = exp\,(c_1 + \boldsymbol{z_{1it}}\delta)\,, \tag{8}$$

where

$$\boldsymbol{z_{1it}} = (size_{it})\,.$$

Maximum likelihood extimation is implemented in order to get consistent and efficient estimators of $\boldsymbol{\beta}$, $\boldsymbol{\delta}$, $\boldsymbol{\gamma}$,$\boldsymbol{\sigma_v^2}$,$\boldsymbol{\eta^2}$.

3 Data

The database has been compiled obtaining data from different sources. The list of MT firms has been provided by Ucimu (national association of builders of machine tool and their components), which has also provided information on the main technological area which firms belong to (see Table 1 for a breakdown of the sample into sub-industries/technological areas). Information on inputs and output have been taken from Bureau Van Dijk's AIDA database, which contains balance sheet information of firms with a turnover of more than 500,000 euro. Information on ownerhip status has been recovered using the Bureau Van Dijk's Ownership Database, while information on district location has been recovered from firms' local units locations and Istat labor local systems classifications.

3.1 Description of variables[16]

Output

- *Output* (l_gross_out_d) is measured as the amount of revenues from sales and services at the end of the year net of changes in inventories and changes contract work in progress. The measure has been deflated[17] using the appropriate two-digit production price index.

[16] *Output*, *Capital* and *Intermediate inputs* are expressed in thousands euro.

[17] All deflators have been computed using Istat national accounts at two-digit level of aggregation: two different deflators have been used for the measure of capital and the measure of output; intermediates inputs have been deflated with the deflator for output.

Inputs

- *Labor* (l_labor) input is measured as the number of employees at the end of the year.
- *Capital* (l_capital_d) input is measured as the nominal value of tangible fixed assets deflated by an *ad hoc* deflator, which has been built using national account data on investments.
- *Intermediate inputs* (l_int_input_d) has been computed as the sum —in the year—of (i) costs of raw, consumumption materials and goods for resale (net of changes in inventories) plus (ii) costs of services. The measure has been deflated using the appropriate two-digit production price index.

All output and inputs are in logs.

In the stochastic frontier time-specific effects (year1-year10, where year1=1998) and and sub-industries specific effects (subindustry1-subindustry10, see Table 1) have been implemented.

Other variables - exogenous factors influencing efficiency

- *Level of vertical (dis)integration* (vert_dis) is measured by the ratio of costs for *Intermediate inputs* (int_input_d) to total production costs in the year.
- *Outsourcing* is measured as the difference between the level of vertical (dis)integration, in year t and the level of vertical (dis)integration in year $t-1$:

$$outsourcing_{i,t} = vert\_dis_{i,t} - vert\_dis_{i,t-1}.$$

An important observation should be stressed at this point. I am aware of problems related to this measure of vertical (dis)integration (and consequently outsourcing). In some sense, this measure is a "variation" of the Adelman index, which is the ratio of value added over sales. Empirical literature on determinants and consequences of vertical integration have tried to overcome its drawbacks (i.e. the fact that it measures just backward integration —asymmetry—, and the fact that it can be problematic to be used in a cross-industry analysis, due to different positions of industries in the overall production chain), suggesting the use of other measures[18]. In this work I use an index which is similar to the Adelman's, both because MT industry is a quite narrowly defined industry, and available data do not permit to build alternative measures of firms' vertical structure/outsourcing. Nonetheless, I

[18] See the use of I/O matrices in Acemoglu, Aghion, Griffith, and Zilibotti (2004) and Acemoglu, Johnson, and Mitton (2005), among others.

try to exploit all possible information from data, building a measure in levels, which is a proxy for level of vertical disintegration of the firm and a measure in differences, which should capture the dynamic process of oustsourcing. The implementation of the two should help to disentangle better the relationships between the vertical structure of the firm, outsourcing, and the efficiency with which it conducts its production process.

- *Size* has been defined as the total number of employees at the end of the year.
- *District location* (max_distretto_mech) is a dummy that takes value "1" for firms which have a local unit (either headquarter or not) which is located in an industrial district (mechanics).
- *Type of ownership* (ownership_2)is a dummy variable which takes value "1" for firms belonging to an industrial group (either national or international): these firms are controlled by other firms and/or control other firms with a share ≥50%.

3.2 Descriptive statistics

From the original sample, some observations have not been taken into account for the analyses: analyzing the sub-sample of firms with either output, or one of the inputs ≤ 1, I discarded 12 very strange observations (comparing that variable value with values for the same firm in other years). Moreover, after a residuals-versus-fitted plot preliminary analysis of an OLS estimation of the model, five more observations have been discarded due to their distance from the cloud of observations. Production frontier computations cannot take into account observations with missing values in output, inputs and exogenous factors. Finally, using a measure in differences for outsourcing, observations in 1998 are not taken into account in the estimation of the frontier; the same fact holds for year1 dummy. That leaves me with an unbalanced panel sample of 500 firms in the period which goes from 1999 to 2007, accounting for 3185 observations.

Table 2 displays descriptive statistics for the whole sample, and Table 3 displays descriptive statistics for the unbalanced panel, that has been used.

3.3 Pre-estimation analysis: on the existence of technical efficiency in the sample

In order to succesfully perform a frontier analysis, it is necessary to analyze the distributions of OLS residuals (Coelli, 1995). The meaning is that there should be a significant bunch of observations below the OLS fit, in order to say that there is technical inefficiency in the sample. In this paper I show two kind of evidences, i.e. statistics for OLS residuals' distribution and graphics of kernel density of OLS residuals.

Table4 shows that while skewness of OLS residuals' distribution is positive, thus casting some doubts on the pertinence of a parametric frontier estimation (Caree, 2002; Li, 1996), its mean is close to zero and its mode is negative. Moreover, Figure 3 shows that the largest share of observations are below the 0-line, thus indicating the existence of small but significant inefficiency in the sample. As a matter of fact more than 55% of observations show negative OLS residuals.

4 Results

4.1 Estimation of the frontier

Estimations have been conducted using Stata 10.1 software[19]. Several models have been estimated. Differences among models relate to vectors of explanatory variables that have been used in each model. Given that I assumed the inefficiency term to follow an exponential distribution, signs of coefficients of exogenous variables on inefficiency variance(η_{it}^2) (which has been modeled) do not change with respect to inefficiency mean (η_{it}). Model0 treats both components of the error variance has constant, i.e. the model is homoskedastic both in noise and in the inefficiency component. Model1 includes size of the firm in both components of the error variance. As we can see, the effect of size is significant just for variance of the noise, while it is not significant for variance of the inefficiency term. In Model2 I introduce the measure of vertical (dis)integration. The sign of the effect is positive, meaning that more the firm is vertically disintegrated (less vertically integrated), larger is the mean and the variance of the inefficiency distribution. That is perfectly in line with hypothesis 1.2, and theories on vertical structure of the firm. In Model3 I introduce also the measure for outsourcing (i.e. first difference of the measure of vertical (dis)integration); interestingly, given the vertical structure, higher outsourcing scores are related to lower mean and variances of inefficiency distribution; moreover, size starts to be significant, and positively related to inefficiency mean and variance. So, we can say that hypothesis 1.1 is confirmed, while hypothesis 2.1 is rejected. In Model4 the dummy for ownership status is introduced, resulting in lower mean and variances of inefficiency distribution for firms belonging to industrial groups (with respect to independent firms); thus, hypothesis 3 is confirmed. Finally, in Model5 I introduce the dummy for industrial district location: firms located in industrial districts are associated to lower mean and variance of the inefficiency distribution, confirming hypothesis 4.

[19]I would like to thank Hung-Jen Wang for providing me with the Stata code that I used for some of my analyses.

4.2 Post-estimation analysis

Efficiency scores can be computed, using either the mean or the mode of the inefficiency distribution, conditional on the observed composed residual (Jondrow, Lovell, Materov, and Schmidt, 1982). The inefficiency index can be computed as:

$$E\left(exp\left(-u_{it}|\hat{\epsilon_{it}}\right)\right),$$

and then the score of efficiency for firm i in time t can be computed as:

$$TE_{it} = \frac{1}{exp\left(u_{it}\right)}.$$

Figure 5 displays efficiency scores by year.

In order to check hypothesis 2.2, which would predict a trade-off between efficiency and "flexibility" in the industry, I computed quartiles of size distribution, and then the mean technical efficiency level for each quartile in each year.

$$\sum_i \frac{TE_{i,t,q}}{I},$$

where I is the number of observations in q, $q = (1, \ldots, 4)$. Then I plotted the time series of mean technical efficiency for each quartile of size. Figure 4 shows trends in each quartile: interestingly, the first quartile shows higher average efficiency than the second and the third one —but not of the fourth one in each year— in the period of contraction of demand (up to 2003), while after this point in time it shows level of average efficiency which are lower than the other quartiles. The most stable quartile is the second one, showing that this size-class has a good balance between efficiency and flexibility. The third and the fourth quartiles are the most subject to cycle: they grow in average efficiency more than the other two quartiles after 2002 (period of demand's growth).

I computed elasticities of output with respect to each input at mean log values of each variable. Table 6 shows output elasticities and return to scale. Return to scale are slightly (but significantly) increasing.

Moreover, I performed some statistical tests concerning parameters of the frontier production function, and those of variances of both error components. Table 7 show the results. Likelihood ratio (LR) test on the inexistence of inefficiency in the model is rejected, and the same result holds fot the null hypothesis of not significant time and sub-industries dummies. LR tests on heteroskedasticity of both error components reject the null hypothesis of no-heteroskedasticity, thus supporting the employed specification of modeling inefficiency by some firm's specific factors. I checked if the vertical configuration of the firm — indicated by both vertical disintegration and outsourcing variables — was significant for inefficiency variation among firms and it was, and finally if the outsourcing process was significant by itself. Interestingly the outsourcing variable results in a significant negative effect for inefficiency, thus suggesting that even after having controlled for the vertical structure, outsourcing has still a significant effect. The Cobb-Douglas restriction have been soundly rejected, thus confirming a superior fit by the translog specification.

The monotonicity/non-monotonicity of relatioships between exogenous variables and technical efficiency can be explored. This can shed light on non-linear relationship between some of exogenous factors and technical efficiency. Starting from firm's size, firm's average size —over time— has been computed and then the sample has been divided into five quintiles by firm average-size. For each quintile the average efficiency score has been computed. The result is depicted in Figure 6, which shows a non-linear relationship between size and efficiency that should be taken into account in modeling the frontier estimation analysis. The same procedure has been applied, taking as sorting criterion levels of vertical disintegration. Figure 7 show the relationship. Finally outsourcing distribution have been divided into quintiles: Figure8 shows the linear relationship.

5 Conclusions and suggestions for further research

This paper examines factors influencing firms technical efficiency in the Italian MT industry; I focused on size, vertical structure of the firm, outsourcing, type of ownership and location in order to explain variability of technical efficiency among firms. Focusing on a single industry, I have obtained reliable measures of technical efficiency and also to control for environmental factors common to all firms (e.g., institutional factors).

The frontier estimation showed a negative relationship between size and technical efficiency, however in the post-estimation analysis a clear non-linearity relationship has emerged, which should be taken into account in futher reasearch on the relationship between size and efficiency. Moreover, a trade-off between efficiency and "flexibility" has been showed in the post-estimation analysis, plotting time-series of average efficiency for each quartile of size.

Firms which belong to industrial groups show higher levels of technical efficiency than independent firms. Firms located in an industrial district are more efficient than firms located elsewhere. All these findings are in line with previous empirical evidence on the impact of such variables on levels of technical efficiency in manufacturing industries.

In addition to these findings, an interesting result emerges: firms which are less vertically integrated are less efficient. But if I introduce the measure of outsourcing which is in differences, given the dynamic nature of the phenomenon, this one has a positive relationship with technical efficiency.

Some limits of the analysis should be noted. The first one relates to the structure of the database, which do not allow for monitoring of firms with a turnover of less than 500,000 Eur. Even if the database can account for more than the 80% of total turnover of the whole industry each year, our database is "biased" to the upper part of turnover distribution. Secondly, concentrating on a single industry/single country analysis has also some drawbacks: results cannot be generalized to other countries.

Results about the vertical *structure* and the outsourcing *process* should be examined more closely. Further steps of the analysis should try to understand which are the phases of the production process (e.g. mechanical components manufacturing, electric/electronic components manufacturing, mechanical and electronic assembly, sales and post-sales services, etc.) which account more for the technical efficiency variability. Moreover, it would be interesting to evaluate the possible existence of different "frontiers" for different vertical structure of firms. If vertical integration relates to a given technology employed by the firm (the way in which inputs and outputs are related), it could affect the shape of the production function, rather than the distance to it. In this case, we could simply detect —as inefficiency— differences in production technology.

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Figure 1: Machine Tools value of production, by Countries; source: Ucimu (2007a)

TAV. 5 - EVOLUZIONE DELLA PRODUZIONE DI MACCHINE UTENSILI NEI PRIMI DIECI PAESI DELLA GRADUATORIA MONDIALE (milioni di euro)

TABLE 5 - EVOLUTION OF MACHINE TOOL PRODUCTION IN THE FIRST TEN MANUFACTURING COUNTRIES IN THE WORLD (million euro)

	1999	2000	2001	2002	2003	2004	2005	2006	2007
1. GIAPPONE/JAPAN	7.074	9.564	8.470	5.712	6.189	7.504	9.382	9.634	9.406
2. GERMANIA/GERMANY	7.167	7.559	8.640	7.427	6.818	7.206	7.876	8.075	9.282
3. CINA/CHINA	1.747	2.445	2.928	2.487	2.635	3.280	4.100	5.653	7.360
4. ITALIA/ITALY	3.519	4.163	4.240	4.007	3.678	3.735	3.912	4.554	5.330
5. COREA SUD/SOUTH COREA	808	1.851	1.521	1.653	1.792	1.985	2.320	3.300	3.319
6. TAIWAN	1.432	2.056	1.825	1.879	1.874	2.321	2.737	3.058	3.193
7. USA	3.980	4.534	3.670	2.570	2.129	2.554	2.788	2.937	2.610
8. SVIZZERA/SWITZERLAND	1.905	1.965	2.319	1.930	1.664	1.878	2.120	2.363	2.543
9. SPAGNA/SPAIN	910	929	990	915	820	822	904	979	1.048
10. BRASILE/BRAZIL	363	517	500	405	418	574	692	762	845

Fonte: elaborazione su dati Gardner Publications e associazioni nazionali

Source: elaboration on Gardner Publications and National Associations data

Figure 2: Machine Tools value of exports, by Countries; source: Ucimu (2007b)

TAV. 9 - PRINCIPALI PAESI ESPORTATORI DI MACCHINE UTENSILI NEL 2007 (milioni di euro e Δ% sul 2006)

TABLE 9 - MAJOR MACHINE TOOL EXPORTING COUNTRIES IN 2007 (million euro and Δ% over 2006)

	Esportazioni/ Exports	Δ% 2007/06		Esportazioni/ Exports	Δ% 2007/06
1. GERMANIA/GERMANY	6.686,9	11,5	15. TURCHIA/TURKEY	316,4	29,0
2. GIAPPONE/JAPAN	6.501,7	-11,4	16. PAESI BASSI/THE NETHERLANDS	302,1	9,9
3. ITALIA/ITALY	2.968,9	12,1	17. CANADA	214,0	-16,8
4. TAIWAN	2.485,8	5,3	18. SVEZIA/SWEDEN	202,6	10,7
5. SVIZZERA/SWITZERLAND	2.215,0	7,4	19. FINLANDIA/FINLAND	202,6	12,6
6. COREA SUD/SOUTH KOREA	1.312,9	2,9	20. BRASILE/BRAZIL	108,8	-10,8
7. USA	1.210,6	-15,6	21. RUSSIA	94,2	4,6
8. CINA/CHINA	1.167,0	23,5	22. DANIMARCA/DENMARK	87,8	0,9
9. REGNO UNITO/UNITED KINGDOM	672,6	-4,1	23. AUSTRALIA	80,2	6,1
10. BELGIO/BELGIUM	636,9	10,6	24. CROAZIA/CROATIA	64,9	-8,5
11. SPAGNA/SPAIN	614,3	10,1	25. ROMANIA/RUMANIA	51,6	-13,3
12. AUSTRIA	548,0	27,1	26. PORTOGALLO/PORTUGAL	35,2	3,5
13. FRANCIA/FRANCE	524,0	2,5	27. MESSICO/MEXICO	30,3	25,2
14. REP. CECA/CZECH REP.	516,1	32,2	28. INDIA	19,4	45,9
TOTALE MONDIALE/WORLD TOTAL				29.878,8	3,2

Fonte: elaborazione su dati Gardner Publications e associazioni nazionali

Source: elaboration on Gardner Publications and National Associations data

Table 1: Sub-industries/Technological areas in the Machine Tool sample

Sub-industries/Technological areas	**Observations**	**Percent**	**Label**
Builders of metal cutting machines	1083	34	subindustry1
Builders of metal forming machines	759	23.83	subindustry2
Builders of unconventional machines	149	4.68	subindustry3
Builders of welding machines	11	0.35	subindustry4
Builders of measuring-control machines	94	2.95	subindustry5
Builders of heat treatment	121	3.8	subindustry6
Builders of mechanical components	712	22.35	subindustry7
Builders of electric/electronic equipment	151	4.74	subindustry8
Builders of tools	105	3.3	subindustry9
Total	**3185**	**100**	

Table 2: Summary statistics for the whole sample

variable	**mean**	**sd**	**min**	**max**	**range**	**N**
gross_out_d	14941.44	53465.88	-126.7564	977747.9	977874.6	4448
capital_d	2165.278	7298.595	0	137786	137786	4459
labor	99.13269	348.5262	1	8478	8477	3836
int_inputs_d	10126.75	37853.09	0	679809.1	679809.1	4448
vert_dis	.6677515	.1245693	0	1	1	4446
outsourcing	.0015584	.064276	-.7451503	.7741279	1.519278	3830
size	99.13269	348.5262	1	8478	8477	3836
ownership2	.2080153	.4059265	0	1	1	5240
max_distretto_mech	.0648855	.2463472	0	1	1	5240

Table 3: Summary statistics for the unbalanced panel, used in analyses

variable	**mean**	**sd**	**min**	**max**	**range**	**¿ N**
gross_out_d	17653.78	60617.14	295.6089	977747.9	977452.3	3185
capital_d	2513.173	7910.932	.9231906	137786	137785.1	3185
labor	102.2126	341.5613	1	8158	8157	3185
int_inputs_d	11986.29	42853.09	118.6262	679809.1	679690.5	3185
vert_dis	.6680691	.1182298	.1715089	1	.8284911	3185
outsourcing	.0004912	.057189	-.2865449	.7741279	1.060673	3185
size	102.2126	341.5613	1	8158	8157	3185
ownership2	.2423862	.428594	0	1	1	3185
max_distretto_mech	.0609105	.2392037	0	1	1	3185

Table 4: OLS residuals statistics

variable	**mean**	**N**
mean_ols_residuals	3.67e-12	3185
mode_ols_residuals	-.8636824	3185
skew_ols_residuals	.2937882	3185

obs. with neg OLS residuals		
	total	**%**
	1776	.5576

Figure 3: OLS residuals kernel

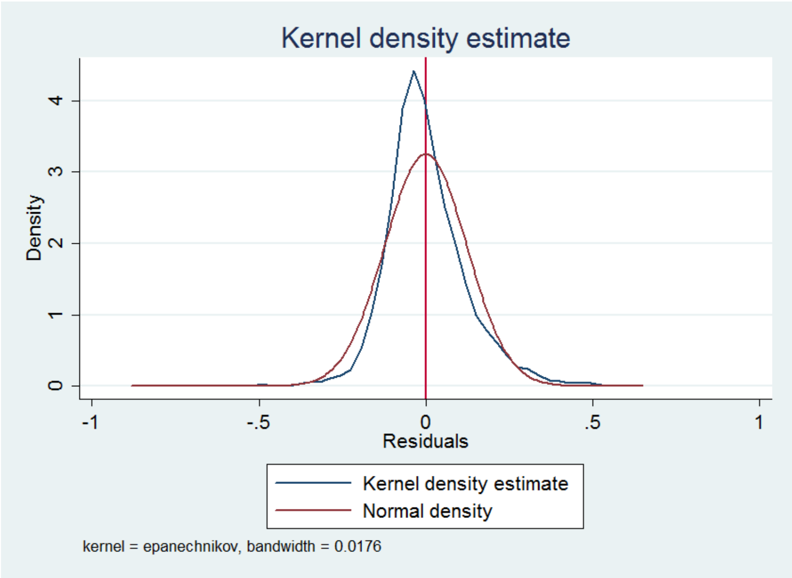


Table 5: Frontier estimation results

variable	Model0	Model1	Model2	Model3	Model4	Model5
	b/_star	b/_star	b/_star	b/_star	b/_star	b/_star
frontier						
l_capital_d	.0398676***	.0372589***	.0364341***	.0373718***	.0426228***	.0403432***
l_labor	.815685***	.8241991***	.8090492***	.8064525***	.8011808***	.8036006***
l_int_inputs_d	.1439643***	.1580825***	.1729044***	.1761615***	.1693879***	.1687675***
l_capital_dsq_half	.0108666***	.0110906***	.011053***	.011389***	.0111574***	.0111517***
l_laborsq_half	.1391982***	.1377492***	.1355973***	.1351283***	.1347947***	.1346394***
l_int_inputs_dsq_half	.1383985***	.1374429***	.1353676***	.1352125***	.1357777***	.1357894***
l_capitalxlabor	-.0011209	-.0002311	-.000249	.0000488	-.0000886	.0002409
l_capitalxint_inputs	-.0097053***	-.0098991***	-.0098286***	-.0103237***	-.010755***	-.0106401***
l_laborxint_inputs	-.1310612***	-.1321575***	-.1300424***	-.1297387***	-.1288843***	-.1292044***
year3	-.0281899***	-.0278183***	-.0276662***	-.028514***	-.0285825***	-.0286516***
year4	-.0864764***	-.0835925***	-.0822641***	-.0822138***	-.0822801***	-.0826841***
year5	-.0976239***	-.0951772***	-.0939985***	-.0925877***	-.0928233***	-.093163***
year6	-.1048657***	-.1012601***	-.1005823***	-.0999479***	-.1001122***	-.0999229***
year7	-.0335197***	-.0330259***	-.0336687***	-.0349322***	-.0346889***	-.0344802***
year8	-.027178***	-.0274497***	-.0278868***	-.0291647***	-.0294461***	-.0294652***
year9	-.0251513***	-.0231804***	-.0237243***	-.0254725***	-.0255303***	-.025698***
year10	-.0141212*	-.0119002	-.0126817	-.0130742	-.0129228	-.0128089
subindustry2	-.0001774	-.00056	-.0003875	-.0006375	-.0006852	-.0005637
subindustry3	-.0165268	-.0148881	-.0172259*	-.0175812*	-.0177448*	-.0159261
subindustry4	-.0103263	-.0112787	-.0117059	-.0115655	-.0174807	-.0147898
subindustry5	.0349674***	.0412514***	.0409594***	.0412818***	.0375965***	.0401102***
subindustry6	.0072507	.0069695	.0079642	.0079763	.0070655	.0090442
subindustry7	.0644897***	.0654929***	.06572***	.0652761***	.0653401***	.0654233***
subindustry8	.0465834***	.043255***	.042418***	.0425885***	.0426057***	.0440387***
subindustry9	.0290267**	.0305239***	.0303036***	.0308745***	.0296238***	.0310218***
Constant	2.929334***	2.857798***	2.815707***	2.803441***	2.834573***	2.840824***
$ln(\eta^2_{it})$ **- inefficiency variance**						
size		.000222	.0002189	.000233*	.0002516*	.000247*
vert_dis			1.681541*	2.053041**	1.906015**	1.784591**
outsourcing				-3.580861**	-3.359639**	-3.378503**
ownership2					-.5420149***	-.4389504**
max_distretto_mech						-1.794685**
Constant	-6.172802***	-6.203995***	-7.330909***	-7.623959***	-7.350837***	-7.247261***
$ln(\sigma^2_{vit})$ **- noise variance**						
size		-.0011944***	-.0011668***	-.0012674***	-.0010982***	-.0011533***
Constant	-4.545278***	-4.44908***	-4.446057***	-4.43502***	-4.458193***	-4.456592***
N	3185	3185	3185	3185	3185	3185

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 4:

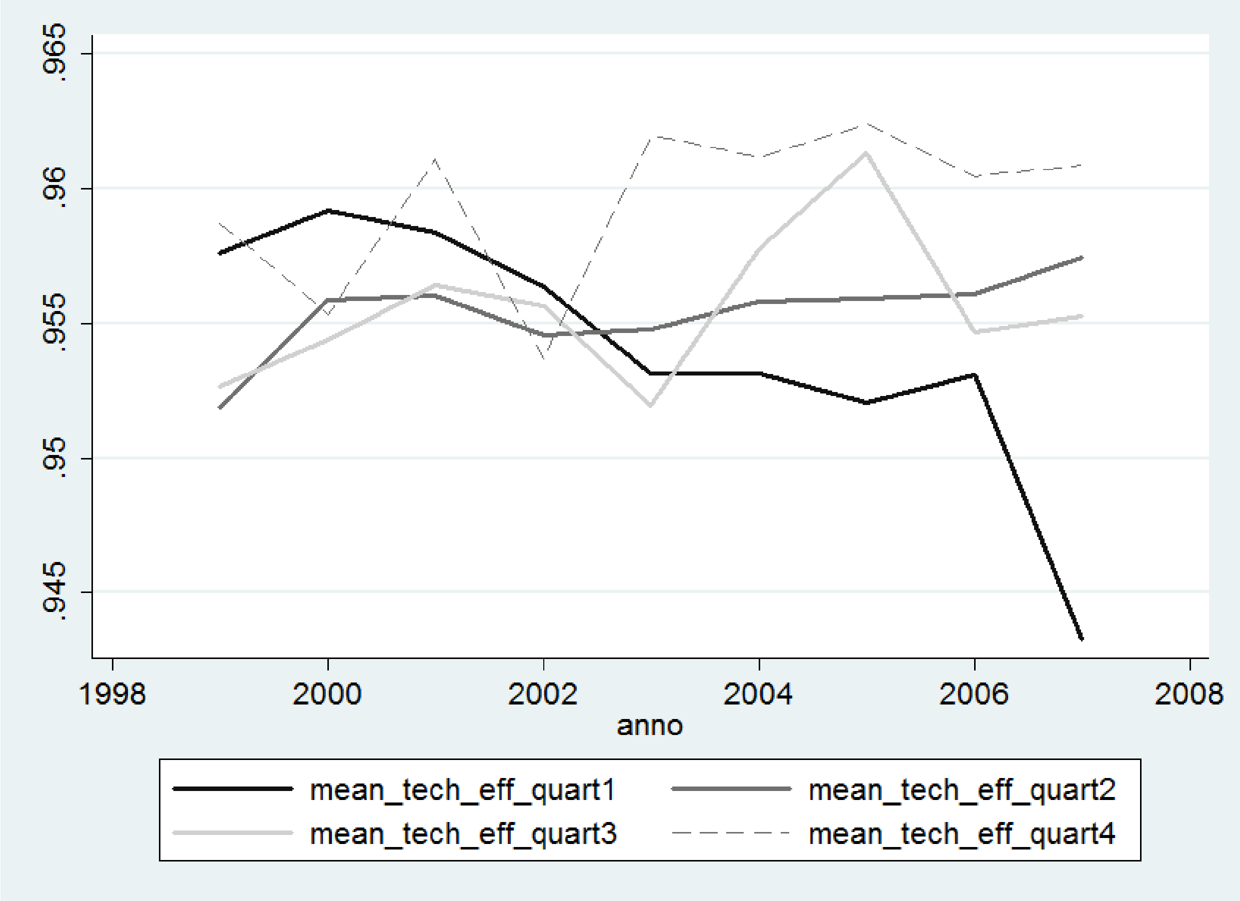


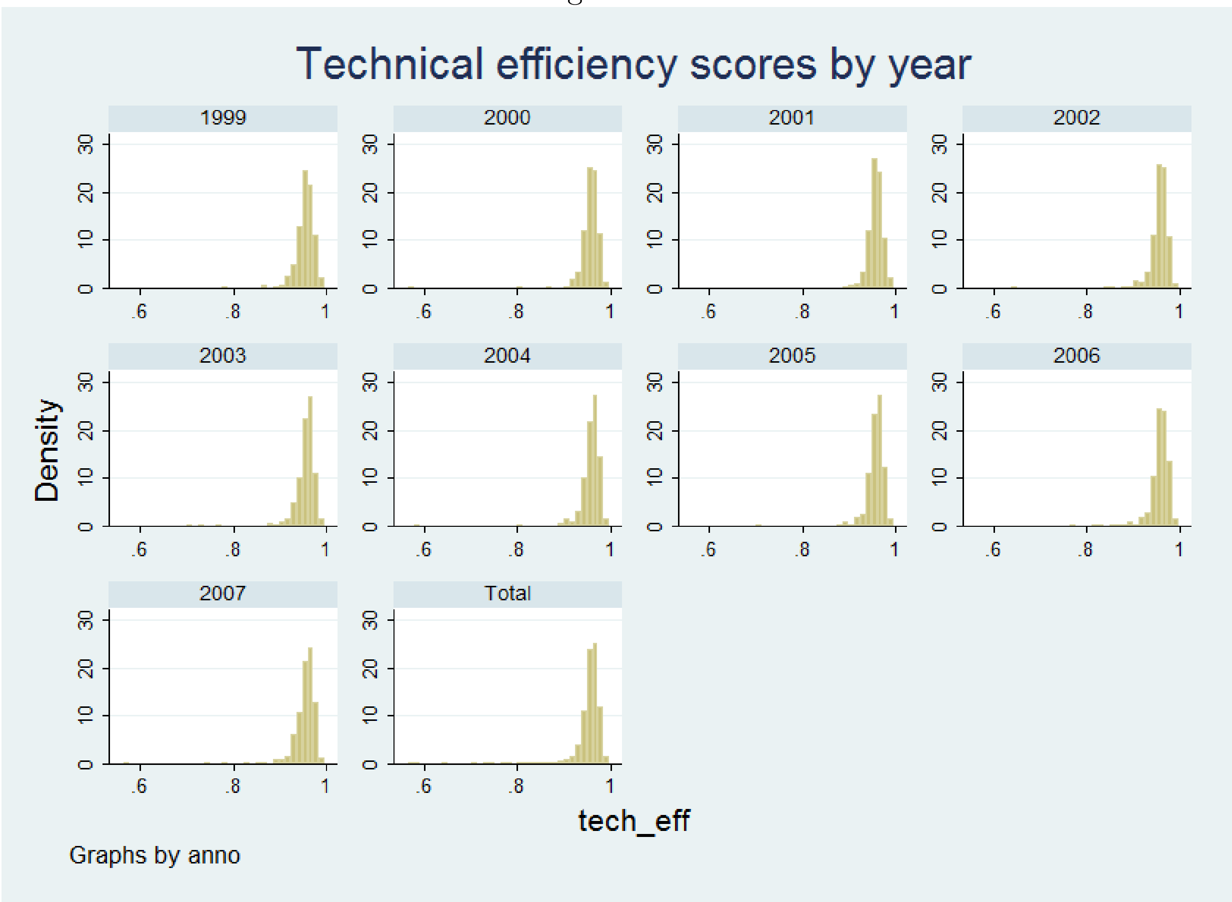
Table 6: Output elasticities and return to scale

Capital	.1165857
Labor	.238939
Intermediate inputs	.7409743
Scale elasticity	1.096499
Elasticities computed at mean log values of frontier input	

Table 7: Tests on parameters of production frontier and parameterized variances

Likelihood Ratio tests on parameters			
Null hp	Conditions	χ^2 statistics	Critical Values (5%)
No inefficiency in the model	$\eta_{it}^2 = 0$	58.16	3.841
Constant Return to Scale (CRS)	$\sum_j \beta_j = 1$ & $\sum_k \beta_{jk} = 0 \, \forall \, j$	16.43	9.488
No sub-industries dummies	$\iota_t = 0 \, \forall \, t$	194.46	15.507
No het in η_{it}^2	$\gamma^{'} = (0, 0, 0, 0)$	33.68	11.070
No het in σ_{vit}^2	$\delta' = (0)$	21.02	3.841
No vertical configuration effect	$\gamma_{vert\_dis} = 0 \, \& \gamma_{outsourcing} = 0$	9.03	5.991
No outsourcing effect	$\gamma_{outsourcing} = 0$	6.08	3.841
Wald tests			
Null hp	Conditions	χ^2 statistics	Critical Value (5%)
Cobb-Douglas restrictions	$\beta_{jk} = 0 \, \forall \, j, k$	792.88	12.592
No time dummies	$\tau_t = 0 \, \forall \, t$	278.58	15.507
$j, k = (capital, labor, intermediate\ inputs)$			

Figure 5:



Technical efficiency scores by year
1999
2000
2001
2002
2003
2004
2005
2006
2007
Total
Density
0
10
20
30
.6
.8
1
tech_eff
Graphs by anno

Figure 6: Average efficiency scores by quintiles of size distribution

Figure 7: Average efficiency scores by quintiles of vertical disintegration distribution

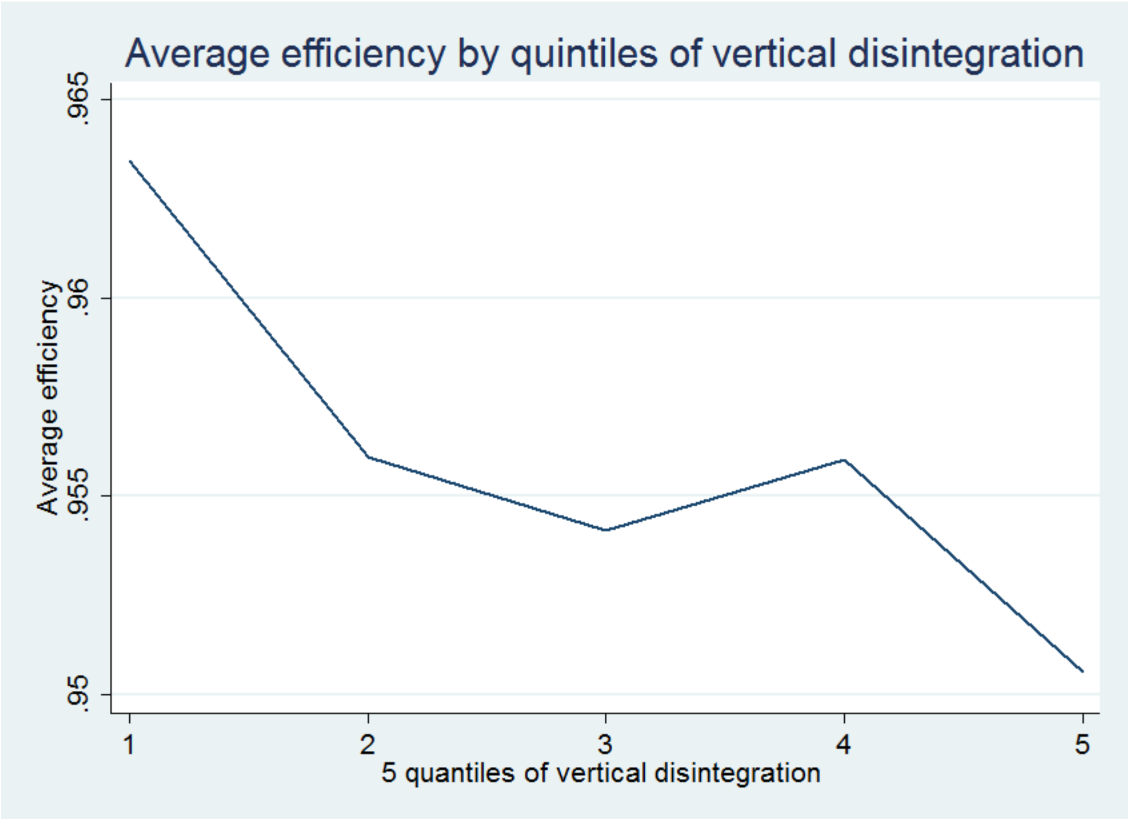


Figure 8: Average efficiency scores by quintiles of outsourcing distribution