Labour-use efficiency in the Italian machinery industry: a non-parametric stochastic frontier perspective

L'efficienza nell'utilizzo del fattore lavoro nel settore della meccanica italiana: un'analisi mediante frontiera stocastica non-parametrica

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Abstract Firms' efficiency is a mainstream in the study of economic growth. Within this broad research area, the present work, conducted as part of the research activities of SOSE S.p.A., analyses the labor-use efficiency in the Italian machinery industry through the application of a non-parametric stochastic frontier model with the aim of suggesting new insights to interpret the recent dynamics of the Italian manufacturing system. An extended panel data of manufacturing Small and Medium Enterprises (SMEs) operating in the mechanical industry for the period 2002-2012 has been extracted (in anonymous form) from the Italian Ministry of Economy and Finance annual survey and used for the implementation of the proposed method.
Abstract *L'efficienza delle imprese è un aspetto cardine nello studio della crescita economica. All'interno di questa area di ricerca, il presente lavoro, condotto nell'ambito delle attivit di ricerca di SOSE S.p.A., analizza l'efficienza nell'utilizzo del fattore lavoro attraverso l'applicazione di un modello non parametrico di frontiera stocastica ad un campione di imprese operanti nel settore della meccanica italiana, con l'obiettivo di proporre nuovi spunti per l'interpretazione delle recenti dinamiche che hanno interessato il sistema produttivo italiano. Il metodo proposto è applicato ad un panel di Piccole e Medie Imprese (PMI) estratto in forma anonima dal database del Ministero italiano dell'Economia e delle Finanze.*

Key words: labor-use efficiency, stochastic frontier, non-parametric, SMEs, GAM

1 Introduction

The measurement of productive efficiency and productivity growth has received increasing attention in the econometrics and statistics research communities with particular emphasis on model estimation. Following this recent trend, the present re-

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search[1] aims at evaluating the different labor-use efficiency for a given set of Italian manufacturing firms through a stochastic frontier model approach [8].
Parametric stochastic frontier models introduced by [1] and [11] specify output in terms of a response function and a composite error term. The composite error term consists of a two-sided error representing random effects and a one-sided term representing technical inefficiency. Since their introduction, several papers have appeared in the literature aiming at improving the structure of the original specification (for extensive reviews of the literature, please see [5] and [9]).
Despite its limited computational complexity, the stochastic frontier approach has an important drawback: the lack of flexibility. Indeed, the assumptions about the functional form of the frontier are often too restrictive and not always appropriated: this issue can introduce substantial bias and might lead to misleading conclusions about the link between inputs and output. To overcome this problem, we adopt in this paper a flexible estimation of the frontier modeled by a Generalized Additive Model (GAM), relaxing the linear assumption between the link fitted values and the linear predictor.
The paper is structured as follows: in section 2, the algorithm is introduced and the results of the empirical application are presented. In section 3 the main conclusions from the study are drawn, discussing potential implications of the empirical findings and providing directions for future research in this area.

2 Methods and Application

Indicating L as the level of employment (number), Y as the production output (turnover), T as the trend variable (year) and K as the level of capital, the labor requirement function [10] can be written as:

$$L = h(Y, K, T). \tag{1}$$

The relevant stochastic frontier model with panel data becomes, in general terms, as:

$$\ln(L_{it}) = h(\ln(K_{it}), \ln(Y_{it}), T; \beta) + v_{it} + u_{it}, \tag{2}$$

where $h(\cdot)$ defines a frontier relationship for the labor input L, for firm i ($i = 1, \ldots, n$) at time t ($t = 1, \ldots, T$) and β is an unknown parameter vector to be estimated. The residual $\varepsilon_{it} = v_{it} + u_{it}$ is composed of a two-sided error term: v_{it} reflecting noise and a one-sided error term $u_{it} \geq 0$ reflecting technical inefficiency. In applications, the two-sided error term is assumed to be normally distributed $v_{it} \sim N(0, \sigma_v^2)$. Several assumptions have been made for the one-sided component, proposing, *e.g.*, half-normal, truncated (other than at zero) normal, gamma and exponential distributions for this term. Following common practice, we assume u distributed as an

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half-normal on the non-negative part of the real number line ($u_{it} \sim |N(0,\sigma_u^2)|$) and that both v and u are identically and independently distributed (iid).
A common practice in empirical studies is to adopt Cobb-Douglas or translog frontier specifications. These functions are widely diffused in economic theory and their properties lead to direct interpretability of the estimation results. However, their use can often generate overparameterized model specifications: in many cases, the specifications used are at best just convenient approximations of the unknown frontier function, and their adoption may lead to incorrect interpretations of the efficiency patterns.

Our setup considers a more flexible estimate of the frontier (2) by considering $h(\cdot)$ as a Generalized Additive Model. In general terms a GAM specification for $h(\cdot)$, given a set of p covariates $X_1, X_2, \ldots, X_p$, may be written as:

$$h(X_1, X_2, \ldots, X_p) = \alpha + \sum_j f_j(X_j), \tag{3}$$

where the f_j's are allowed to be arbitrary nonlinear functions of the set of covariates [6]. Additive models retain most of the desirable properties of linear models, while increasing computational flexibility. One of the main benefits of linear models is that they are fairly straightforward to interpret: in order to know how the prediction changes as you change X_j , you only need to know β_j . The partial response function f_j plays the same role in an additive model.
For the estimation of the stochastic frontier model (2) we consider the following two-step procedure as proposed by [13]:

1. estimation of the conditional expectation $E(L|Y,K,T)$ (i.e. the "mean" frontier) of the model (2) by means of GAMs (3);
2. estimation of the error term parameters (σ_v, σ_u) using the method of moments approach [13].

This approach allows us to smooth both firm and time effects, which are formally included in a linear fashion in the model. Having obtained the pseudo maximum-likelihood estimates of σ_v and σ_u, the biased intercept is corrected by means of the moments of the GAM residuals, to obtain the "stochastic frontier", and estimates of technical inefficiency u_{it} are calculated using the method proposed by [7].

The application has been carried on a balanced sample of 5821 SMEs extracted from the Italian Ministry of Economy and Finance annual survey (Studi di Settore) operating in the machinery industry during the 2002-2012 period: the choice of this sector is motivated by its key role in the national manufacturing system, considering that the engineering sector accounts for more than 42% of total manufacturing added value [4]. The study of labor use efficiency appears to be particularly relevant in Italy, where, despite the efforts made by the national governments in the recent past, a number of legislative and institutional constraints still affect the efficient use of labor in several industries (for an extensive review of the topic, see [14]): these weaknesses contribute to explain the structural gap in labor productivity existing between Italy and other advanced countries [2]. Despite the rigidities of the Italian labor market, the level of employment protection varies considerably across em-

ployee groups: in this context, a key role is played by the Wage Guarantee Fund (*Cassa Integrazione Guadagni*), a temporary lay-off scheme available to particular groups of firms that is used to counterbalance labor market rigidity and allocate the optimal level of labor after economic shocks. Aside from influencing the unemployment risk of permanent employees, this asymmetry across employment protection regulations has a potential positive impact on labor-use efficiency of the eligible firms. In this context, the study of employment use dynamics is particularly relevant to evaluate the speed of adjustment in the labor input use after the recent economic crisis and to assess the degree to which labor-use efficiency has varied among different groups of firms where employment protection was different. These issues have been addressed by evaluating the labor efficiency dynamics over time and relative to the use of Wage Guarantee Fund.

In equation (1), output (Y) is measured in terms of turnover, labor (L) as the number of employees and capital (K) is proxied by the machinery capital value. The financial variables included in the specification have been deflated using production price indices extracted from the Italian Bureau of Statistics (ISTAT) database.

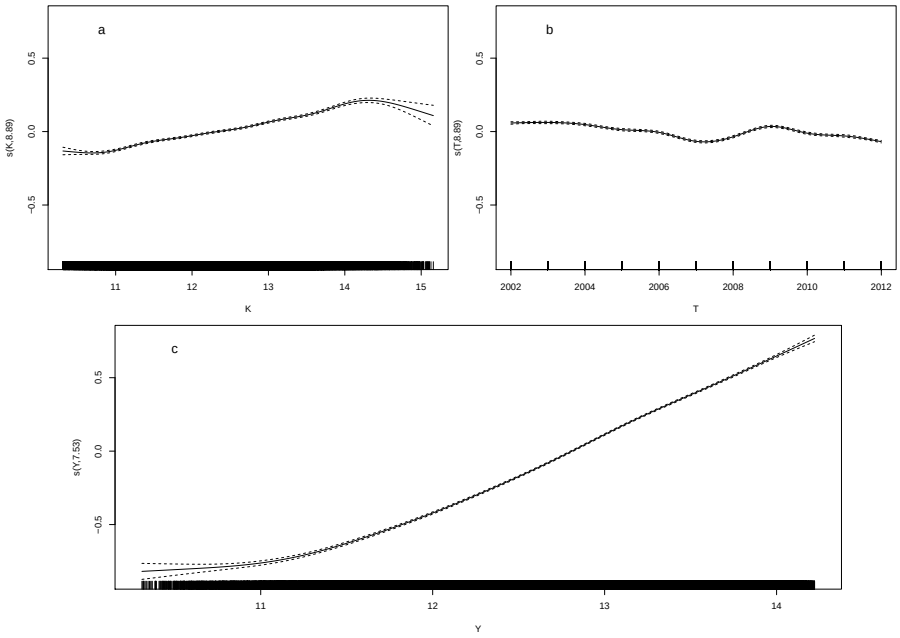

Fig. 1 Contributions of the model terms to Labour with respect to capital K (1.a), time T (1.b) and output Y (1.c).

Figure 1 shows contributions of the model terms to Labour, that is the smooth terms associated to time, output and capital. The dashed curves show pointwise approximate two standard error limits for the fitted curves. There is a strong evidence about the significance of all covariates. The results show the presence of a persistent level

of labor-use inefficiency over time (Fig 1.b), thus confirming previous findings on the stagnating trend of labor productivity in the Italian manufacturing sector [12].
The mean estimated values of labor-use efficiency are reported in Table 1 (*Total*): during the time span considered, individual labor-use efficiency ranged from 24.2% to 97.3% with the mean value of 82.6%; therefore, on average, labor is overused by 17.4%. There is not a strong difference among years.
Considering the estimates of labor-use efficiency are firm and time specific, the results can be examined in further detail by focusing on firms that have used Wage Guarantee Fund during the time span considered. The results of the estimates (Table 1) show that this subset of firms have achieved a higher level of labor-use efficiency during the 2005-2012 period[2]: therefore, the empirical evidence suggests that this policy measure has been effective in reducing the inefficiency associated with the rigidities of the Italian labor market.

Table 1 Labour-use efficiency in the Italian machinery industry, time span 2002-2012.

Year	Total	Wages Guarantee Fund	No Employees
2002	0.824	NA	0.756
2003	0.827	NA	0.758
2004	0.823	NA	0.756
2005	0.828	0.876	0.763
2006	0.822	0.877	0.757
2007	0.829	0.879	0.767
2008	0.821	0.870	0.756
2009	0.830	0.870	0.772
2010	0.825	0.857	0.774
2011	0.828	0.862	0.785
2012	0.828	0.868	0.779

Finally, the focus of the analysis of labor-use efficiency is moved to the subset of firms that do not use standard forms of employment such as part-time, casual, fixed-term, temporary agency workers (*No Employees*): the results of the estimates show that labor input use, holding capital and output constant, is higher than average among these businesses. The empirical evidence highlights the presence of higher labor-use inefficiency, even if the existing gap tends to decrease over time.

3 Conclusions

This work provides a novel framework to evaluate efficiency of Italian manufacturing firms, in an attempt to partially fill the existing gap in the relevant literature due essentially to the lack of firm level data. We propose a flexible procedure finding

[2] Information on Wage Guarantee Fund is not available in the database before 2005. However, the use of this policy tool was rather limited between 2002 and 2004, i.e. the years excluded from the empirical analysis [3]

new insights associated to the labor-use efficiency dynamics of Italian manufacturing firms in the recent past. The results show the presence of a persistent level of labor-use inefficiency in the sample used for the analysis, thus confirming previous findings on the stagnating trend of labor productivity in the Italian manufacturing sector: in this context, the empirical evidence suggests that the use of Wage Guarantee Fund have been effective in mitigating the inefficiency associated with the rigidity of the Italian labor market.
Possible directions for future research include the implementation of alternative specifications of the inefficiency component u_{it}, integrating internal and external factors associated with tangible and intangible factors such as R&D, human capital, public infrastructure and degree of internalisation. Furthermore, the analysis could be moved forward by estimating the employment elasticity with respect to the covariates with particular regard to time: according to [10] this component can be interpreted as technical change.

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