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Changes in Multifactor Productivity in Italy from 1998 to 2004: Evidence from Firm-Level Data Using DEA

by

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Abstract

This paper presents a firm-level analysis of the multifactor productivity that has been recently observed in Italy. DEA techniques are applied to the firm-level data collected within the annual surveys on the economic accounts of enterprises carried out by the Italian National Statistical Institute (ISTAT). MFP changes occurred during the period 1998-2004 have been measured for 25 industries and have been decomposed into technological change (shift in the production frontier) and change in relative technical inefficiency (due to modifications in the distance of the single firms from the frontier). The results of this decomposition has been discussed and interpreted. Outcomes highlight a stagnation in Italian MFP trend, in particular a decrease in MFP is registered for many economic sectors.

***J.E.L. Classification Codes*: D2, L2, O4**

***Keywords*: Technological change, Technical efficiency, Productivity, DEA**

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1. Introduction

The recent productivity slowdown in the economies of a group of industrialized countries, notably Spain and Italy, is increasingly attracting the attention of analysts and policy makers. Previous estimates such as those based on OECD productivity database have in fact remarked[1] a decreasing productivity pattern with negative rates for multifactor productivity (MFP) in some countries. Italy recorded, in the period 1995-2005, 5 years with a negative growth of MFP and an average annual rate of -0.1% during the period.

Industry level estimates made available by Italian National Statistical Institute (ISTAT)[2] confirm a negative performance for multifactor productivity that is slowing down for nearly all industries from year 2000. MFP dynamics has deeply changed since during 1980-1995 MFP growth rate were positive and contributed to the growth of labour productivity more than capital but after 1995 MFP has started to decrease without providing any relevant contribution to labour productivity. These estimates where confirmed by further studies made by Milana (2006) Mas, Milana and Serrano (2008) at industry level within the EU KLEMS project.

Thus the estimates obtained using using economic index numbers with sectoral data can be usefully complemented with a decomposition of multifactor productivity at firm level. The data are collected from the economic accounts of medium- and large-sized enterprises in annual surveys carried out by ISTAT. The methodology is based on Data Envelopment Analysis (DEA) following previous applications made by Milana and Zeli (2002)(2004a)(2004b) in the study of impact of ICT and other determinants on productivity in the Italian manufacturing industries.

Productivity measurement based on economic index numbers aggregating inputs and outputs at industry level is not directly comparable with DEA results, which are based on the identification of a common technical frontier by selecting the best-practice firms operating in the same sector. With this methodology, changes in MFP are obtained as a compound effect of the shift in the technical frontier and changes in the average distance of each production unit from the frontier. Moreover, in the economic index number approach, each industry is assumed to allocate all production resources efficiently, whereas DEA takes advantage of the higher level of disaggregation of data over firms to distinguish inefficient firms from those that can be considered to be "best-practice".

Several problems may be encountered with the two alternative approaches mentioned here. Most of them may be related to the homotheticity of technical changes and the non-neutrality of inefficiency (distance from the frontier) with respect to the outputs or inputs. Homothetic separability is a necessary and, in general, sufficient condition for a measure to be invariant with

[1] Oecd, Productivity database: growth of MFP (per cent) in http://stats.oecd.org/WBOS/Index.aspx.
[2] Istat, Misure di produttività, Statistiche in breve, 10/05/2007. Rome

respect to the reference variables. If such condition is not fulfilled, then we might obtain inconsistent results. However, the two techniques may be affected differently from non-homotheticity of changes since the scope of aggregation is defined along different dimensions and domains.

The measurement proposed here is aimed at obtaining further elements concerning productivity performance in Italy during the recent years from a set of micro data which are used to construct the national economic accounts. The question is whether the low profile of productivity growth in the recent years in Italy can be attributed to a relatively small structural and technical change rather than to scarce improvements in technical efficiency of the single production units. According to the innovation approach the question is also whether industries are characterized by a relevant degree of technological competitiveness shifting the production function (and recording gains in terms of technical change) or a more traditional behaviour is prevailing in each industry: competition is mainly based on the optimization of costs (efficiency gains) and technical change is an exogenous feature.

In our previous analysis (Milana-Zeli, 2004b, p. 271), DEA-like indexes of MFP change in Italy during the period 1996-99 showed that the productivity slowdown observed at the aggregate level of the economy has been mainly due to "negative" technological change due to a declining performance of the best-practice production units, which have not been completely offset by improvements in technical efficiency. A slight decrease (-0.39%) in MFP was due to a declining effect of technological change (-0.96%) and a positive change in technical efficiency (0.56%). Since "negative" technological change is often difficult to envisage, this could be interpreted as another type of technical efficiency when the best-practice frontier is assumed to have remained unchanged.

During the same period, MFP change varied widely among the industries both in sign and magnitude. The industries with the high increases in MFP have been *Office, accounting and computing machines, Shipbuilding, Post and Telecommunication, Iron and Steel*. Negative changes in MFP could be noted in many other industries. Slight decreases were registered in *Aircraft and spacecraft, Pulp, paper and paper products, Textiles, apparel and leather, Pharmaceuticals, Machinery and equipment, Wood products, Medical and precision instruments, Wholesale and retail trade*. In these industries the decrease in MFP had been the outcome of "negative" technological change. The industries that suffered the greatest decrease in MFP were *Real estate, renting and business services, Health and social work, Computer services and related activities, Petroleum, coal products, R&D activities, Hotel and restaurants, Transport and storage, and Other community and social work*. Except for R&D activities, decreases in MFP were mainly due to negative effects of technological change. A substantial portion of productivity stagnation observed in those years can be explained by the relatively low accumulation of information and communication technologies.

The results obtained in our previous study encourage us to update our analysis of productivity growth in the period 1998-2004 by applying DEA within the industrial breakdown of the EU KLEMS project. We may consider the results obtained as useful information concerning an important part of industry production, although the firm-level data in the more recent surveys carried out by ISTAT are not fully comparable with those made for earlier periods. The rest of the paper is organized as follows: Section 2 presents the methodology, section 3 describes the data used, section 4 presents the results obtained, section 5 concludes.

2 The methodology

2.1 Measuring MFP, relative technical efficiency, and technological change

The empirical analysis starts with the identification of the best-practice (or technological) frontier of production in each industry defined as the set of the most efficient production points in the space of outputs and inputs. Data Envelopment Analysis, a linear programming technique by which the production frontier is put in evidence as the piece-wise-linear convex hull formed by referring to the most efficient production points is the method adopted for the identification of the best practice frontier at industry level. Using DEA results, Färe et al. (1994) have constructed the Malmquist index of MFP growth, defined by Caves, Christensen and Diewert (1982), and have shown how these indexes can be decomposed into changes in the firms' distance from the efficient frontier (technical efficiency changes) and the shift of the frontier itself (technological change).

The DEA technique applies a separate linear programming problem for each of the firms or production units within an examined industry. Consider N firms in each industry (with N varying across the examined industries). Let the inputs and outputs of the ith firm be respectively represented by the K-order column vector $\mathbf{x}_i$ and the M-order column vector $\mathbf{y}_i$. The input and output data for all N firms form the $K\times N$ input matrix $\mathbf{X}$ and the $M\times N$ output matrix $\mathbf{Y}$, respectively.

Assuming the general case, which includes variable returns to scale, the output-oriented measure of the ith firm's technical efficiency is derived from the data envelopment form defined by the following optimisation problem:

(1)
$$\begin{aligned} & max_{\phi_i,\lambda} \quad \phi_i \\ \text{subject to} \quad & \mathbf{Y\lambda} - \phi_i \mathbf{y}_i \geq \mathbf{0}_M \\ & \mathbf{x}_i - \mathbf{X\lambda} \geq \mathbf{0}_K \\ & \mathbf{N1}' \cdot \boldsymbol{\lambda} = 1 \\ & \boldsymbol{\lambda} \geq \mathbf{0}_N \end{aligned}$$

where $1\leq\phi_i<\infty$, with ϕ_i being a scalar, $\boldsymbol{\lambda}$ is an N-order column vector of constants, **N1** is an N-order column vector of ones. The convexity constraint ($\mathbf{N1}'\cdot\boldsymbol{\lambda} = 1$) ensures that an inefficient production unit is only "benchmarked" against production units of a similar size (in the case of constant returns to scale, this constraint is not imposed, the λ weights sum up to a value different from one and the benchmarking may be made against production units that are substantially larger or smaller than the examined *i*th production unit). The value (ϕ_i - 1) is the proportional increase in output(s) that could be obtained by the *i*th production unit with the input quantities held constant. The output-oriented measure of technical efficiency (TE_i) of the *i*th production unit is given by:

$$TE_i = 1/\phi_i \tag{2}$$

TE_i varies between zero and one ($0< TE_i \leq 1$, where $TE_i = 1$ means that the *i*th production unit is fully efficient and operates on the best-practice frontier).

Technical efficiency measures can be depicted in the left-hand side of Figure 1 in the case of constant-returns to scale and in the right-hand side of the same Figure1 in the case of decreasing returns to scale. The technology is represented, for simplicity, by the one-output one-input piece-wise linear frontier. For the inefficient production unit operating at point P, the Farell input-oriented measure of TE corresponds to AB/AP, while the output-oriented measure of TE corresponds to CP/CD. As it can be seen in Figure 1, the input-and output-oriented measures are equivalent (AB/AP = CP/CD) with the constant returns to scale technology.

Malmquist productivity index numbers can be defined by using the concept of distance functions. The output distance function is defined as:

(1) $$d^T(x,y) = min\{\delta: (y/\delta) \in \tilde{A}^T(x)\}$$

where $\tilde{A}^T(x)$ is the set of all possible levels of the output *y* for a given technology T and the input level *x*. The optimal value of the scalar δ^* (= $d_o(x,y)$) permits us to calculate the maximal proportional expansion of the output for a given input level. It is equal to unity if *y* is on the frontier, otherwise it is less (greater) than one if the output, *y*, is positioned below (above) the frontier the production possibility set (the location of the output level above the frontier is technically unfeasible, but it is possible to virtually construct such an outcome in comparisons of actual levels of *y* in one period and the frontier existing in another period). We note that $d_o(x,y)$ has the meaning of technical efficiency, that is

(2) $$d^T(x,y) = TE$$

The Malmquist (output oriented) index of MFP change between period 0 and period 1 is given by

(3) $$TFP_M(y_0, x_0, y_1, x_1) \equiv \left[\frac{d^0(y_1, x_1)}{d^0(y_0, x_0)} \cdot \frac{d^1(y_1, x_1)}{d^1(y_0, x_0)} \right]^{\frac{1}{2}}$$

The measure of change in MFP can be depicted in the left-hand side of Figure 2 in the case of constant-returns to scale and in the right-hand side of the same Figure 2 in the case of decreasing returns to scale. The technology is represented, for simplicity, by the one-output one-input piece-wise linear frontier. The MFP variation observed between the inefficient production unit operating at point P^t and that operating at point P^{t+1} is given by $(OA^{t+1}/OC^{t+1}):(OA^t/OC^t)$. Dividing the two ratios at the numerator and denominator by the average productivity on the respective frontiers of efficient production, given by CD/OC at time t and CE/OC at time t+1, yields

$$\frac{\frac{OA^1}{OB^1}}{\frac{OA^0}{OB^0}} \cong \frac{\frac{OA^1}{OB^1}}{\frac{B^1D^0}{OB^1}} : \frac{\frac{OA^0}{OB^0}}{\frac{B^0C^0}{OB^0}} = \frac{OA^1}{B^1D^0} : \frac{OA^0}{B^0C^0} = \frac{d^0(x_1, y_1)}{d^0(x_0, y_0)}$$

$$\frac{\frac{OA^1}{OB^1}}{\frac{OA^0}{OB^0}} \cong \frac{\frac{OA^1}{OB^1}}{\frac{B^1D^1}{OB^1}} : \frac{\frac{OA^0}{OB^0}}{\frac{B^0C^1}{OB^0}} = \frac{OA^1}{B^1D^1} : \frac{OA^0}{B^0C^1} = \frac{d^1(x_1, y_1)}{d^1(x_0, y_0)}$$

with strict equalities in the case of constant returns to scale (since, in this case, $B^1D^0/OB^1 = B^0C^0/OB^0$ and $B^1D^1/OB^1 = B^0C^1/OB^0$).

The distance functions cannot be computed without knowing the frontier production set. A number of different methods have been devised to estimate this frontier[3]. The DEA approach outlined above is one of the convenient alternatives. Generalising to the case of variable returns to scale the DEA-like approach proposed by Färe *et al.* (1994) for the estimation of the distance functions necessary to construct the Malmquist index defined (2) yields:

(4) $$[d^1(\mathbf{y}_1, \mathbf{x}_1)]^{-1} = max_{\phi_i, \lambda} \quad \phi_i$$

$$\text{subject to} \qquad \mathbf{Y}_1\boldsymbol{\lambda} - \phi_i \mathbf{y}_{i1} \geq \mathbf{0}_M$$

[3] See, for example, Milana and Zeli (2002) for references to the different methods proposed in the literature.

$$\mathbf{x}_{i1} - \mathbf{X}_1\boldsymbol{\lambda} \geq \mathbf{0}_K$$
$$\mathbf{N1}' \cdot \boldsymbol{\lambda} = 1$$
$$\boldsymbol{\lambda} \geq \mathbf{0}_N$$

(5) $$[d^0(\mathbf{y}_0, \mathbf{x}_0)]^{-1} = max_{\phi_i, \lambda} \quad \phi_i$$

subject to
$$\mathbf{Y}_0\boldsymbol{\lambda} - \phi_i \mathbf{y}_{i0} \geq \mathbf{0}_M$$
$$\mathbf{x}_{i0} - \mathbf{X}_0\boldsymbol{\lambda} \geq \mathbf{0}_K$$
$$\mathbf{N1}' \cdot \boldsymbol{\lambda} = 1$$
$$\boldsymbol{\lambda} \geq \mathbf{0}_N$$

(6) $$[d^1(\mathbf{y}_0, \mathbf{x}_0)]^{-1} = max_{\phi_i, \lambda} \quad \phi_i$$

subject to
$$\mathbf{Y}_1\boldsymbol{\lambda} - \phi_i \mathbf{y}_{i0} \geq \mathbf{0}_M$$
$$\mathbf{x}_{i0} - \mathbf{X}_1\boldsymbol{\lambda} \geq \mathbf{0}_K$$
$$\mathbf{N1}' \cdot \boldsymbol{\lambda} = 1$$
$$\boldsymbol{\lambda} \geq \mathbf{0}_N$$

(6) $$[d^0(\mathbf{y}_1, \mathbf{x}_1)]^{-1} = max_{\phi_i, \lambda} \quad \phi_i$$

subject to
$$\mathbf{Y}_0\lambda - \phi_i \mathbf{y}_{i1} \geq \mathbf{0}_M$$
$$\mathbf{x}_{i1} - \mathbf{X}_0\lambda \geq \mathbf{0}_K$$
$$\mathbf{N1}' \cdot \lambda = 1$$
$$\lambda \geq \mathbf{0}_N$$

These four linear programming problems must be solved for each i^{th} firm in the sample. In problem (5), the data point can lie above the frontier considered for comparison and referring to a different period. In the case of technical progress, it would possible to obtain a value of ϕ_i<1. Similarly, in the case of technical regress (which is, however, less likely to occur), problem (6) would obtain a value of ϕ_i>1.

The Malmquist index of MFP change defined by (2) can be decomposed as follows

(7)
$$TFP_M(y_0, x_0, y_1, x_1) = EC \cdot TC = \frac{d^1(y_1, x_1)}{d^0(y_0, x_0)} \left[\frac{d^0(y_1, x_1)}{d^1(y_1, x_1)} \cdot \frac{d^0(y_0, x_0)}{d^1(y_0, x_0)} \right]^{\frac{1}{2}}$$

where

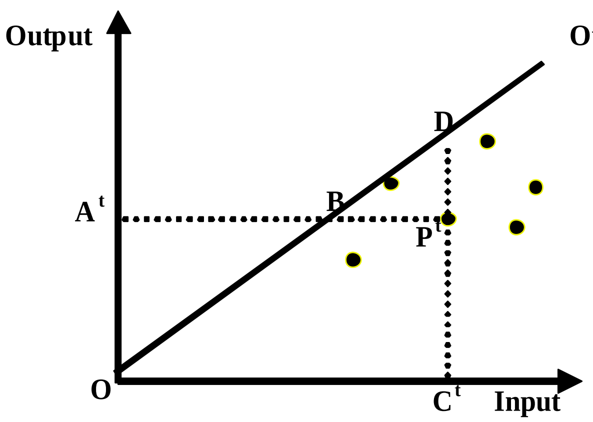
(8)
$$EC \equiv \frac{d^1(y_1, x_1)}{d^0(y_0, x_0)}$$

is an index efficiency change between periods 0 and 1 (which corresponds to the ratio $(OA^1/B^1D^1)/(OA^0/B^0C^0)$ in Figures 2a and 2b) and

(8)
$$TC \equiv \left[\frac{d^0(y_1, x_1)}{d^1(y_1, x_1)} \cdot \frac{d^0(y_0, x_0)}{d^1(y_0, x_0)} \right]^{\frac{1}{2}}$$

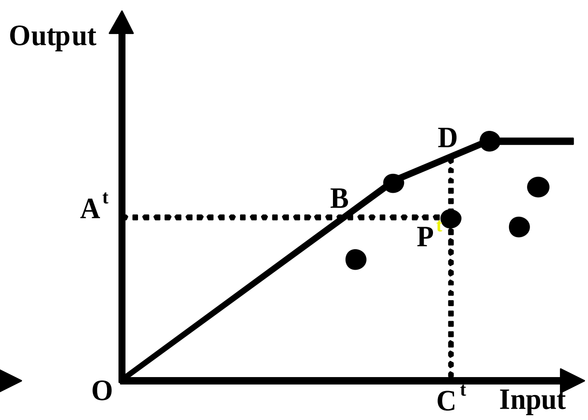
is an index of technological change (which is represented by $[(B^1D^1/B^1D^0)/(B^0C^1/B^0C^0\ )]^{1/2}$ in Figures 2a and 2b).

Figure 1a



(a) Constant returns to scale

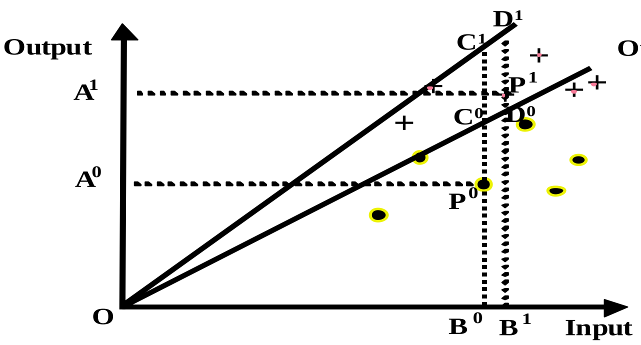
Figure 1b



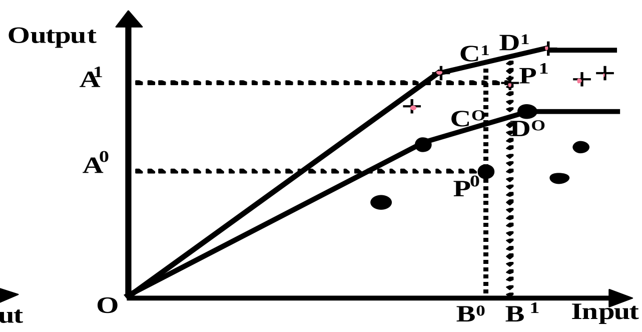
(b) Decreasing returns to scale

Figure 2a

Figure 2b



(a) Constant returns to scale



(b) Decreasing returns to scale

3. Description of the data

The main purpose of the study is to check the evolution of MFP growth of the Italian firms with 20 persons employed and over at industry level. Data are referred to a panel of enterprises with 20 persons employed or more from 1998 to 2004. The features of the panel are compatible with the requirements of economic information complete, consistent and comparable over time.

The panel is retrospective; it is mainly based on cross-sectional enterprises surveys micro-data with the integration of administrative micro-data for ensuring the matching of items over time and of eventual non respondents. The cross-section enterprises surveys that characterise the panel show a widespread overlap time by time and a relevant longitudinal component.

The panel is originated by three main sources: the SCI (Sistema dei Conti delle Imprese) survey referring to enterprises with 100 persons employed and more, the PMI (Piccole e Medie Imprese) survey concerning enterprises with less than 100 person employed and an administrative database (balance sheet transmitted to Commerce Chambers by enterprises) for all capital firms.

SCI is a detailed survey on economic and financial accounts of enterprises and it is carried out annually in Italy by ISTAT. The scope is to cover all the enterprises resident in Italy with at least 100 persons employed from 1998 to 2004. Information for firms with less than 100 person employed, is made available by PMI: a yearly sample survey on economic and financial accounts.

SCI and PMI collect data concerning profit-and-loss accounts and balance sheets. Information regarding employment, investment, personnel costs and some regional items is also collected. Even if the data collection has the purpose of the full coverage of the total population (or of the sample) of target enterprises there is a problem of non responses that has to be treated through missing data imputation procedures. Economic information requested by SCI and PMI meets the requirements of guidelines of the 4th EEC Directive scheme under the Italian national Law No. 69 of 26 March 1990 and the national Legislative Decree No. 127 of 9 April 1991 (see, for example, ISTAT, 2007).

Thus, the total population of Italian enterprises with at least 20 employees counted around 70,000 firms in 1998 and over 78,000 units in 2004 (Table 3.1).

Table 3.1 – Number of enterprises, persons employed and value added in Italy by size class – Year 1998-2004.

Size class	Number of enterprises	Persons employed	Value added *(millions of euro)*
		1998	
1-19	3,835,354	8,439,142	212,948
20 or more	69,858	5,636,859	282,503
Total	3,905,212	14,076,001	495,450
		2004	
1-19	4,189,593	9,550,696	263,471
20 or more	78,289	6,562,146	348,562
Total	4,267,882	16,112,842	612,033

Source: Italian SBS data warehouse

Notwithstanding the enterprises with 20 person employed represent only 2 per cent of total enterprises in terms of employment and value added they have a share of 40 per cent and 60 per cent respectively.

The rationale behind the definition of retrospective panel has to draw all the links between answering firms in 1998 survey with 2004 survey respondents

Since events of M&A and wave non responses may affect the capacity of representativeness of the panel and may increase panel attrition, a complex strategy of integration was carried out. All demographic events involving enterprises over a fixed threshold (250 person employed) were considered and the longitudinal links between enterprises were pieced together. Non responses were integrated by means of an administrative source (balance sheet transmitted to Commerce Chambers by enterprises).

At the end of the process the representativeness of the universe of Italian enterprises with 20 persons employed and over was quite satisfactory especially for big size enterprises: the panel included about 21,800 firms that are nearly 30 per cent of total population in both years. In terms of persons employed the enterprises included in the panel represent a share of 49.1 per cent in 1998 and a share of 41.3 per cent in 2004.

The analysis of productivity growth is carried out using quantities of outputs and inputs linked in the DEA models described in second section. Namely output is approximated by the firms' turnover and three inputs have been defined:

- number of person employed (as a proxy of labour factor),
- intermediate costs (purchases for goods and services)

- tangible and intangible assets (as capital inputs).

Since all the relevant variables, originally collected by the ISTAT surveys, are in monetary values at current prices they have been deflated by means of appropriate indexes.

Output values have been deflated by means of the indexes of producer prices at industry level. Tangible capital (at book value) has been deflated by means of the price index for investment goods, whereas the aggregate monetary value of intermediate inputs has been deflated by means of a price index coming out from the aggregation of market price indexes for each input category. The adopted deflators are elaborations of price indexes coming from the Euklem project field. Price indexes values are expressed in *euro-lire* related to the base year 2000.

According to its main economic activity, each enterprise is originally associated with an industry defined within the NACE Rev.1.1 classification at an intermediate detail level (sections and sub-sections) equivalent to the 30 branches National Account classification. The database includes 25 sectors representing quite all activities in industry and services except for agricultural and finance activities.

4. Empirical results

The results obtained by applying the DEA-like Malmquist indexes of MFP change are shown in Tables 4.1 and 4.2. The main conclusions are the following:

1. The mean values of technical efficiency are quite high and the coefficients of variation are relatively low in manufacturing industries reflecting a tendency of the firms to concentrate near the efficient frontier. By contrast, most services tend to have lower mean values of technical efficiency and relatively high coefficients of variation reflecting a tendency of the production units to be in the average more distant from the sectoral efficient frontier but scattering more sparsely in efficiency performance. Most manufacturing industries show an average degree of technical efficiency around 80 per cent with a coefficients of variation around 20 per cent, whereas most services have achieved an average degree of technical efficiency around 60 per cent or even lower with coefficients of variation between 40 and 60 per cent. This evidence suggests that the lack of competitiveness and strong protection of incumbent firms in the service sectors prevent them in many cases to pursue first-best production results.

2. On the average, during the period 1998-2004, MFP slightly increased (0.55%), due to a negative effect of technological change (-0.99%) and a positive change in technical efficiency

(1.56%). Since a negative technological change is often difficult to rationalize, it could be explained as another type of technical efficiency with the additional assumption of an unchanged best-practice frontier.

3. During the same period, MFP growth has recorded a high degree of heterogeneity between the industries (see Table 4.2). The industries with the greatest increase in MFP have been *Coke, refined petroleum products and nuclear fuel* (+23.7%), *Transport, storage and communication* (+7.3%), *Wood and products of wood and cork* (+3.4%). Note that all these industries (but the wood sector) have registered positive values in the technical efficiency change and negative values in the technological change component on the pattern of the previous DEA based analysis, namely for years 1996-99 (se also Milana-Zeli, 2004b, p. 271).

Positive but smaller changes in MFP have been observed in *Chemicals* (+0.1%), *Wholesale and retail trade* (+1.0%), *Rubber and plastic products* (+0.6%), *Construction* (+0.5%). Almost all these changes are the net results of negative changes in technology and positive effects from changes in technical efficiency. This confirms the evidence found in our previous analysis.

4. Negative changes in MFP, which are mainly due to a negative technological change, have been noted in other industries like *Electrical and optical equipment* (-0.5%), *Pulp, paper, and paper products* (-0.8%), *Food products, beverage and tobacco* (-1.4%), and *Machinery* (-1.4%).

5. The industries that have suffered from the more relevant slowdown of MFP are *Hotels and restaurants* (-12.2%), *Real Estate, renting and business activities* (-9.9%), *Leather and leather and footwear* (-6.1%), *Mining and quarrying of energy producing materials* (-5.5%) *Health and social work* (-5.1%). In some of these sectors, decreases in MFP were due to negative effects of technological changes whereas in others they can be attributed to efficiency changes.

6. The MFP estimation of the overall study has been deeply affected by the impact of oil shocks in the fuel industry. Excluding *Coke, refined petroleum products and nuclear fuel* affect total averages that notably change as follows: MFP records a slight decrease (-0.53%) due to a negative effect of technological change (-0.76%), not fully compensated by a positive performance in technical efficiency (0.25%). The transformation sector of energy and raw materials provides a relevant contribution on MFP growth in the overall Italian economy reversing the algebraic sign of its relative change over the period considered.

The high growth of MFP of the fuel sector (characterized by a positive sign for efficiency coupled by a negative one for technical change) is, probably, due to the four-fold rising oil prices during the examined period. If the transformation sector of energy and raw materials is excluded, a declining MFP emerges in the whole economy and particularly in some advanced services sectors.

Table 4.1 (a) Technical efficiency DEA estimations by economic sector (variable returns to scale). Means, standard deviations and coefficients of variations - Years 1998-2004.

		1998	2004
MINING AND QUARRYING OF ENERGY PRODUCING MATERIALS	*mean*	0.888	1.000
	standard deviation	0.251	0.000
	cv	0.283	0.000
MINING AND QUARRYING EXCEPT ENERGY PRODUCING MATERIALS	*mean*	0.724	0.768
	standard deviation	0.183	0.164
	cv	0.253	0.213
FOOD PRODUCTS, BEVERAGES AND TOBACCO	*mean*	0.631	0.612
	standard deviation	0.164	0.140
	cv	0.259	0.229
TEXTILE AND TEXTILE PRODUCTS	*mean*	0.666	0.600
	standard deviation	0.136	0.133
	cv	0.204	0.222
LEATHER, LEATHER AND FOOTWEAR	*mean*	0.660	0.698
	standard deviation	0.179	0.169
	cv	0.271	0.242
WOOD AND PRODUCTS OF WOOD AND CORK	*mean*	0.823	0.758
	standard deviation	0.103	0.122
	cv	0.125	0.161
PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	*mean*	0.587	0.586
	standard deviation	0.143	0.148
	cv	0.243	0.253
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	*mean*	0.685	0.823
	standard deviation	0.210	0.155
	cv	0.307	0.189
CHEMICAL AND CHEMICAL PRODUCTS	*mean*	0.727	0.728
	standard deviation	0.138	0.142
	cv	0.189	0.195
RUBBER AND PLASTICS PRODUCTS	*mean*	0.705	0.705
	standard deviation	0.126	0.139
	cv	0.179	0.197
OTHER NON-METALLIC MINERAL PRODUCTS	*mean*	0.639	0.695
	standard deviation	0.174	0.166
	cv	0.273	0.239
BASIC METALS AND FABRICATED METAL PRODUCTS	*mean*	0.631	0.468
	standard deviation	0.141	0.146
	cv	0.224	0.312
MACHINERY, NEC	*mean*	0.563	0.481
	standard deviation	0.145	0.134
	cv	0.258	0.278

Table 4.1 (b) Technical efficiency DEA estimations by economic sector (variable returns to scale). Means, standard deviations and coefficients of variations - Years 1998-2004.

ELECTRICAL AND OPTICAL EQUIPMENT	*mean*	0.610	0.639
	standard deviation	0.156	0.165
	cv	0.255	0.258
TRANSPORT EQUIPMENT	*mean*	0.684	0.510
	standard deviation	0.142	0.209
	cv	0.208	0.409
MANUFACTURING NEC; RECYCLING	*mean*	0.689	0.650
	standard deviation	0.149	0.139
	cv	0.216	0.214
ELECTRICITY, GAS AND WATER SUPPLY	*mean*	0.695	0.684
	standard deviation	0.246	0.227
	cv	0.354	0.332
CONSTRUCTION	*mean*	0.344	0.248
	standard deviation	0.163	0.155
	cv	0.475	0.624
WHOLESALE AND RETAIL TRADE	*mean*	0.416	0.491
	standard deviation	0.171	0.169
	cv	0.412	0.345
HOTELS AND RESTAURANTS	*mean*	0.624	0.658
	standard deviation	0.183	0.173
	cv	0.294	0.263
TRANSPORT AND STORAGE AND COMMUNICATION	*mean*	0.375	0.452
	standard deviation	0.237	0.203
	cv	0.632	0.448
FINANCE, INSURANCE, REAL ESTATE AND BUSINESS SERVICES	*mean*	0.947	1.000
	standard deviation	0.107	0.000
	cv	0.112	0.000
REAL ESTATE, RENTING AND BUSINESS ACTIVITIES	*mean*	0.498	0.392
	standard deviation	0.206	0.199
	cv	0.413	0.506
EDUCATION	*mean*	0.789	0.762
	standard deviation	0.198	0.218
	cv	0.251	0.286
HEALTH AND SOCIAL WORK	*mean*	0.680	0.693
	standard deviation	0.176	0.174
	cv	0.259	0.251
OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	*mean*	0.589	0.578
	standard deviation	0.197	0.203
	cv	0.334	0.352

Table 4.2 - DEA-like Malmquist indexes of MFP change and its components in the Italian industries, 1998-2004 (average values)

Industry	Efficiency change	Technical change	Multifactor productivity change
	(4)	*(5)*	*(6) = (4)+(5)*
		(Rate of change in percentage)	
MINING AND QUARRYING OF ENERGY PRODUCING MATERIALS	-36.38	30.82	-5.55
MINING AND QUARRYING EXCEPT ENERGY PRODUCING MATERIALS	6.30	-6.29	0.00
FOOD PRODUCTS, BEVERAGES AND TOBACCO	-0.10	-1.21	-1.41
TEXTILE AND TEXTILE PRODUCTS	-11.88	8.62	-3.25
LEATHER, LEATHER AND FOOTWEAR	10.17	-16.25	-6.08
WOOD AND PRODUCTS OF WOOD AND CORK	-14.16	17.65	3.44
PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	-1.41	0.60	-0.80
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL o	29.42	-5.76	23.67
CHEMICAL AND CHEMICAL PRODUCTS	-1.71	1.78	0.10
RUBBER AND PLASTICS PRODUCTS	0.30	0.30	0.60
OTHER NON-METALLIC MINERAL PRODUCTS	13.28	-10.43	2.86
BASIC METALS AND FABRICATED METAL PRODUCTS	-28.90	27.46	-1.51
MACHINERY, NEC	-8.56	7.05	-1.41
AELECTRICAL AND OPTICAL EQUIPMENT	2.08	-2.63	-0.50
TRANSPORT EQUIPMENT	-40.95	38.59	-2.43
MANUFACTURING NEC; RECYCLING	-2.84	0.30	-2.53
ELECTRICITY, GAS AND WATER SUPPLY	7.88	-10.87	-2.94
CONSTRUCTION	-35.52	35.98	0.50
WHOLESALE AND RETAIL TRADE	24.29	-23.19	1.00
HOTELS AND RESTAURANTS	9.17	-21.44	-12.22
TRANSPORT AND STORAGE AND COMMUNICATION	25.54	-18.27	7.33
FINANCE, INSURANCE, REAL ESTATE AND BUSINESS SERVICES	3.73	-19.97	-16.13
REAL ESTATE, RENTING AND BUSINESS ACTIVITIES	-37.11	27.16	-9.87
EDUCATION	7.60	-5.76	1.78
HEALTH AND SOCIAL WORK	0.90	-5.98	-5.13
OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	-1.01	-2.02	-3.15
TOTAL*	1.56	-0.99	0.55

* Weighted averages. The used weight is output (turnover)

5. Conclusion

The results obtained with previous DEA based analyses of firm-level data confirm that the productivity slowdown in Italy has been mainly due to a "negative" technological change not completely offset by improvements in technical efficiency. At the aggregate level, both capital and labour inputs have positively contributed to output growth in 1996-98 and 1998-2004, with the exception for ICT capital which has played a marginal role. MFP growth has been negative, after one peak reached in 2000. The contribution of MFP to the growth of labour productivity has been negative during the years 2000-2003 and marginally positive during the whole period 1995-2006, leaving all the increase in labour productivity attributed to non-ICT capital input growth.

With reference to the results of our DEA-based analysis of ISTAT survey data, we can distinguish two subperiods:

1) During the years 1996-98, firms have adopted a traditional market strategy based on efficiency gains (positive technical efficiency) leaving in the background long term investment strategies aimed at improving production techniques. The prevailing pattern was a short-run cost optimizing management investing more in fast return capital inputs than in technology and innovation. Competition was based mainly on lowering costs while maintaining the same technological structure rather than innovating products and processes, although those years were characterized by the ICT boom. At the aggregate level, gross investments increased by +9.7 per cent.

2) During the years 1998-2004, firms have attained efficiency loss only partially offset by a positive technological change. The arising pattern is a management strategy trying to invest in new technologies in order to take advantage of new products and new systems of productions has resulted in an overall price in terms of negative change in efficiency. Investments increase by +17.9 per cent in real terms but the technological gap between best performers and 'normal' performers has widened.

According to an innovation Schumpeterian approach, the key feature is the research for business strategy oriented towards innovation in order to overcome the shortcomings of a low MFP growth profile. In some industries, the best performers are characterized by a relevant technological innovation, but other competitors are lagging behind for various reasons, such as small size of firms, scarce channel of access to new technologies and product innovation, protected local markets. Technological change is still widely regarded as an "exogenous" factor that can be engaged by following foreign leaders only after its exploitation has been proved workable. An imitation-based strategy seems to have been the preferred route while maintaining a certain flexibility in the choice of the mix of production.

On the other hand, some few industries are characterized by innovative firms with an aggressive behaviour. They have managed to differentiate their products and/or processes taking advantage, at the same time, of temporary monopoly positions. They have managed to produce new and improved goods and services while introducing innovative ways of production. Because of these reasons, they have registered a scarce economic performance in the short run.

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