

Malmquist Productivity Index. An Empirical Application to the Italian Banking Sector

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Una applicazione empirica al settore bancario italiano

Domenico Summo, Pasquale Quatela

Dipartimento di Scienze Statistiche, Università degli Studi di Bari
Via Camillo Rosalba n° 53, 70124 – Bari, e-mail: dosummo@dss.uniba.it

Riassunto: L'attenzione rivolta alla produttività nel settore bancario italiano riveste particolare interesse in relazione alla competitività tra le banche italiane e tra queste e quelle europee. Scopo del lavoro è la stima di un indice TFP (Total Factor Productivity) nel settore bancario italiano con un approccio metodologico innovativo rispetto all'impostazione classica: la metodologia Malmquist-DEA. L'applicazione dei teorici Malmquist Productivity Index stimati non-parametricamente mediante stimatori Data Envelopment Analysis, ha condotto alla generazione di indici TFP specifici per le principali 36 banche italiane osservate negli anni 1997-2001. Questi indici sono stati scomposti in indici di efficienza tecnica ed indici di progresso tecnologico.

Keywords: Total Factor Productivity (TFP), Malmquist Productivity Index (MPI), Data Envelopment Analysis (DEA), Efficiency Index, Technology Index, Banking Sector.

1. Introduction

In the last years of the second millennium, the Italian banking system has experimented important normative changes and the start of the globalization processes of markets has induced the banks towards a more competitive system in which it is essential to define continuous strategies to preserve, when it isn't possible to strengthen, their own competitive positions. In this evolutionary scenario, a leading role has been played by the Bank of Italy which has promoted a policy of expansion finalized to reduce the fragmentariness of credit offer, true operational tie to the strengthening of the competitive positions in comparison to the foreign competitors. The necessity to operate in wider and competitive context, desirable in order to increase the general efficiency of the banking systems, has often induced several banks to sacrifice the prudential attitude in the moment of the evaluation of the credit risk for a greater operational capacity and a greater market share. This behaviour has often had negative effects on the profitability of the banking enterprise. Since the profitability is function of the product between productivity and price recovery, for the banking management it becomes of vital importance to pay greater attention to the available resources by redefining the productive organization in order to optimize their use. In pursuing this aim the management may rely on the contribution of performance indicators, among which those used to estimate the change in the Total Factor Productivity (TFP) that make available useful *ex-ante* indications, even if they furnish *ex-post* data. Therefore from this viewpoint, the problems that traditionally torment the researchers of the banking sector productivity assume an ever-growing importance, first of all the definition and measurement of the banking product.

In this paper an empirical answer to the cognitive demands of the temporal changes of the Italian banking sector TFP is experimented by using a non-parametric, frontier approach, in opposition to the non-parametric, non-frontier approach (TFPI, Index number of the TFP, i.e.: TFP index of Törnqvist, Fisher, Solow, Kendrick), that is the Malmquist-DEA methodology¹.

2. An application of the Malmquist-DEA methodology

MPI-DEA is the acronym of Malmquist Productivity Index-Data Envelopment Analysis. It always deals with TFPI, or better, estimators of the TFP changes, but unlike those of non-frontier approaches type, they may be decomposed into their principal components, or effects, that is: 1) change in technical efficiency, EI (Efficiency Index), or catching-up effect, 2) change in productive technology, TI (Technology Index), or technological shift effect. For any observed bank², these two components explain the role played by the changes in its technical efficiency (i.e. Farrell efficiency) and the common productive technology (technological progress/regress) respectively, in defining its TFP changes. A bank-specific MPI-DEA estimator originates by making the theoretical MPI empirical by implementing the DEA estimators³. It may be defined as follow:

$$\text{MPI-DEA} = \underbrace{\hat{MPI}_{I,C}}_{\text{TFPI}} = \underbrace{\frac{\hat{D}_{I,C}^{t+1}(\mathbf{x}_S^{t+1}, \mathbf{y}_S^{t+1})}{\hat{D}_{I,C}^t(\mathbf{x}_S^t, \mathbf{y}_S^t)}}_{\text{EI}} \cdot \underbrace{\left[\frac{\hat{D}_{I,C}^t(\mathbf{x}_S^t, \mathbf{y}_S^t)}{\hat{D}_{I,C}^{t+1}(\mathbf{x}_S^{t+1}, \mathbf{y}_S^{t+1})} \right]}_{\text{TI}}^{0,5}$$

MERGEFORMAT (1)

in which both the components are ratios (or indexes) among Shephard oriented distance functions, whose true but unknown reciprocal values are estimated by implementing a DEA estimator that yields a non-parametric estimate of the true and unknown Farrell technical efficiency measure. The “ $\hat{\cdot}$ ” on the D denotes it deals with an estimator of the true but unknown distance function⁴; C denotes the DEA estimator assumes Constant Returns to Scale (CRS); S denotes that Strong Disposability is assumed about the outputs and inputs⁵; I denotes that in order to define the estimator of the involved distance

¹Of course, the empirical results of this work cannot rise to the rank of “numerical truth” with reference to the theoretical concepts relative to the productivity changes, since they represent rather a contribution to the empirical experimentation of a methodology whose potentialities deserve to be investigated, above all in a productive context characterized by multi-input & multi-output technology like the banking one.

²The implementation of the MPI-DEA estimator, unlike those TFPI of non-frontier approaches type, needs the availability of a cross-sectional data for each time period (e.g. year $t = 1, \dots, T$) included in the observation interval (T years), that is a panel data which normally consists only of a sample (of productive structures) of the investigated economic reality.

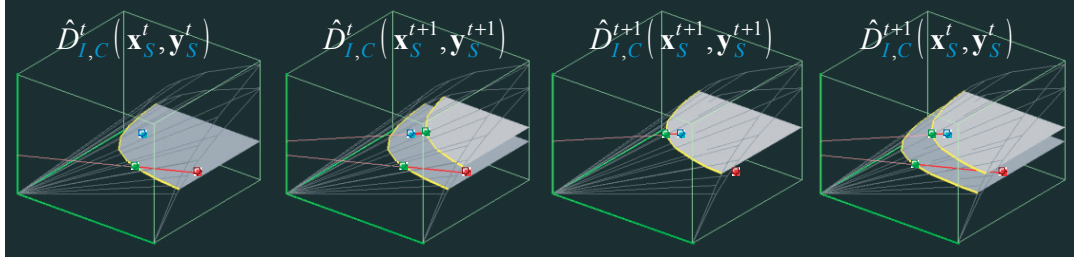
³In order that the MPI-DEA estimator be properly interpreted as a TFPI, it is necessary the theoretical MPI be implemented by means of a DEA estimator defined to a production frontier which it is assumed to exhibit Constant Returns to Scale (CRS), i.e. the DEA-CRS estimator.

⁴ $\hat{D}_{I,C}(\mathbf{x}_S, \mathbf{y}_S)$ and $\hat{MPI}_{I,C}$ estimate the distance function $D_I(\mathbf{x}, \mathbf{y})$ and MPI respectively.

⁵For each observed bank, the DEA estimator measures the radial distance between the Farrell-efficient production frontier, non-parametrically estimated as a piece-wise linear envelopment of the input-output combinations (vectors) of all the banks included in the observed sample (cross-sectional data), and its location in the input-output space. It yields an estimate of the true and unknown Farrell technical efficiency

functions (hence, of the involved Farrell technical efficiency measures) and therefore of the MPI-DEA one, the input orientation has been preferred to the output one⁶; finally $\mathbf{y}$ and $\mathbf{x}$ denote output vector and input one respectively, while t and $t+1$ denote two time periods of reference. Hence the MPI-DEA estimator (1) needs four different estimates of distance function: two of within-period type, two of cross-period type (see Figure 1).

Figure 1: Simulation of the estimate of the Shephard distance function⁷



This methodology has been applied to a panel data concerning the principal 36 Italian banks observed in the interval 1997-2001, after specifying a technology model for the banking industry. For each of the observed banks the component EI has been decomposed into the following subcomponents: Pure Technical Efficiency Index (PTEI), Scale Efficiency Index (SEI), Input Congestion Index (ICI). The use of the NIRS estimator (Non-Increasing Returns to Scale) has made it possible to identify the type of returns to scale experimented by each banks. This same methodology has been applied by Rapacciuolo (2000) a panel data concerning the principal 20 Italian banks observed in the interval 1993-1996. Compared with that work, in the present one a more wide panel data is analysed; two further MPI-DEA estimator decompositions are implemented; they have been identified the *innovators*, i.e. those banks which have shifted the production frontier over the interval 1997-2001; moreover, for each of such years and for every bank-specific input, it has been defined the necessary level in order to project the inefficient bank on the production frontier; in the end, a (*naïve*) Bootstrap Monte Carlo algorithm has been applied to yield bank-specific confidence intervals for the MPI-DEA estimator.

Succinctly, during 1997-2001, with reference to 36 banks as a whole, TFPI has signalled an overall increase of about 10% (i.e., about 2.5% per year). In particular, its trend has been increasing over the first three two-year periods, while it has fallen during the last one: only 0.85%. Such a trend must be ascribed to the technological progress. Actually, the positive technological shift effect (TI ▲) during the analyzed five-year

measure, whose reciprocal value represents a non-parametric estimate of the true and unknown (i.e. theoretical) Shephard distance function value.

⁶Opting for the input [output]-orientation, the distance is estimated in the hyperplane where vector output [input] remains constant and it is defined by the ratio between the normal of the input [output] vector of the observed productive structure (bank, in the present work) once it has been projected on the estimated production frontier and the same input [output] vector, as originally observed in the sample. The DEA estimator individualizes just the corresponding frontier vector, which is the projection point on the estimated production frontier of the observed input [output] vector.

⁷Each boxes simulates (in the 3D space) the estimate of one of the necessary four true and unknown distance functions. The red [blue] point denotes the input-output vector observed at time t [$t+1$], the green one denotes the corresponding projection point on the surface of the appropriate productive technology, i.e. on the estimated production frontier (transparent envelopment), precisely on its appropriate section (yellow piece-wise-linear isoquant). The red segment denotes the input distance function.

period has taken up the negative catching-up effect (EI ▼). The decomposition of EI has pointed out that its overall decrease (1.0078 ▼) is due to an overall decrease of SEI e ICI which have deteriorated of about 0.22% and 0.13% per year on average respectively, while PTEI has improved of about 0.16% per year on average. The overall correlation between the TFP growth and technical progress counts also if results are analyzed by groups of banks of the same size. The growth of the large banks TFP has been higher than that of the major and medium banks one (about 1.5% and 3.7% extra respectively). Moreover, large banks have experienced an increase of EI, even if its SEI has deteriorated (see Table 1)⁸. During the analyzed period *Banca Pop. Etruria e Lazio*, *Banca Pop. Emilia Romagna*, *Unicredito Italiano* have experienced the highest TFP growth.

Table 1: MPI-DEA estimator of the TFP Index and its decomposition

Years/Size	TFPI	EI	TI	PTEI	SEI	ICI
Averages* of all the observed banks (1997-2001)						
1997/98	0.9879 ▲	1.0027 ▼	0.9852 ▲	1.0014 ▼	1.0048 ▼	0.9966 ▲
1998/99	0.9797 ▲	1.0011 ▼	0.9696 ▲	0.9946 ▲	0.9962 ▲	1.0103 ▼
1999/00	0.9497 ▲	0.9989 ▲	0.9507 ▲	1.0010 ▼	1.0090 ▼	0.9891 ▲
2000/01	0.9915 ▲	1.0050 ▼	0.9866 ▲	0.9966 ▲	0.9989 ▲	1.0095 ▼
1997/01	0.9029 ▲	1.0078 ▼	0.8959 ▲	0.9936 ▲	1.0090 ▼	1.0053 ▼
Averages* within banks of the same size (1997/01)						
Major	0.8946 ▲	1.0211 ▼	0.8762 ▲	1.0000 –	1.0298 ▼	0.9915 ▲
Large	0.8798 ▲	0.9551 ▲	0.9211 ▲	0.9611 ▲	1.0121 ▼	0.9819 ▲
Medium	0.9173 ▲	1.0312 ▼	0.8896 ▲	1.0083 ▼	1.0012 ▼	1.0214 ▼

* Geometric means. Note that: Index < [>] 1 signals increase [decrease]; rate of change (%) = (1 – Index)·100.

References:

- Caves D. W., Christensen L. R., Diewert W. E. (1982), The Economic Theory of Index Number and the Measurement of Input, Output, and Productivity, *Econometrica*, vol. 50, n° 6, 1393-1414.
- Färe R., Grosskopf S., Norris M., Zhang Z. (1994), Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries, *The American Economic Review*, vol. 84, n° 1, 66-83.
- Löthgren M., Tambour M. (1999), Bootstrapping the data envelopment analysis Malmquist productivity index, *Applied Economics*, vol. 31, 417-425.
- Rapacciuolo C. (2000), Analisi dell'efficienza del sistema bancario secondo la metodologia non parametrica, in: Bagella M., Giannola A. (Eds.), *Performance, assetto proprietario e internazionalizzazione del sistema bancario italiano*, CNR-ISFSE, Il Mulino, Bologna, 197-229.
- Ray S. C., Desli E. (1997), Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Comment, *The American Economic Review*, vol. 87, n° 5, 1033-1039.
- Wheelock D., Wilson P. W. (1999), Technical Progress, Inefficiency, and Productivity Change in U.S. Banking, 1984-1993, *Journal of Money, Credit, and Banking*, vol. 31, n° 2, 212-234.

⁸ Disaggregated results for each bank are available from the authors upon request.