Economics Bulletin

Volume 38, Issue 1

Determinants of total factor productivity growth of Tunisian manufacturing firms

Khaled Thabet
Higher school of economic and commercial sciences of Tunis

Abstract

Using a panel of Tunisian manufacturing firms observed over the 1998–2006 period, The purpose of this paper was to decompose the total factor productivity (TFP) growth into technological progress and changes in technical efficiency taking advantage of the DEA-based Malmquist productivity index. Recent developments in bootstrapping techniques are used to give more insight concerning the significance of the point estimates from the linear programming and total factor productivity estimates. Results show that, in average, technical efficiency score is around 59% which implies that the firms in our sample can, on average, increase production by 41% using the same levels of inputs in order to match the frontier. Across industries, TFP growth has been heterogeneous. TFP of manufacturing sector increased in average by 7.55% over the period 1998-2006. This performance was due mainly to technical efficiency change (5.77%) and a relatively low technological change (1,67%).

Research in Quantitative Economics of Development Laboratory (LAREQUAD). E-mail : khthabet@yahoo.com. I want to thank John Conley, Baccouche Rafik and the two anonymous referees of Economics Bulletin for their comments and suggestions.
Citation: Khaled Thabet, (2018) "Determinants of total factor productivity growth of Tunisian manufacturing firms", *Economics Bulletin*, Volume 38, Issue 1, pages 336-348
Contact: Khaled Thabet - khthabet@yahoo.com.
Submitted: February 21, 2016. **Published:** February 09, 2018.

1. Introduction

Since the pioneering work by Solow (1957) an interesting body of theoretical and empirical studies has been devoted to analyze the factors explaining economic growth. Most of these studies concluded that productivity growth is clearly one of the fundamental sources that provide society with an opportunity to increase welfare, economic growth and economic prosperity. Moreover, Krugman (2005) found that a difference between countries in terms of productivity will translate into (roughly) a proportional difference in living standards.

In this sense, since 80's Tunisia have adopted a set of economic reforms affecting all sectors of the economy, particularly manufacturing given the importance of the industrial sector in the scheme of growth and development, to put the national economy on a path of high and sustained growth. In fact, to prepare to the openness and trade liberalization[1], Tunisia have implemented accompanying policies mainly the structural adjustment program (PAS) in 1986, and the upgrade program in 1995 aimed at strengthening the performance potential of Tunisian firms to modernize the productive behavior that appears to be a key factor of productive efficiency and firms performance. Indeed faced with an increasing intensification of competition caused by market liberalization, Tunisian firms are increasingly subject to improvement requirement of their productive behavior. In this context, Tunisia, whose objective is to fully integrate into the global economy, grants to the productivity improvement a top priority to meet the challenges of employment and growth.

Therefore, it is important to understand the sources of productive inefficiency and factors that may affect the total factor productivity, TFP, in the productive sector to implement, on solid ground, appropriate economic policies to enhance the productive performance of Tunisian firms. From a policy perspective, the assessment of growth is important as it serves as guide for allocating resources and investment decision making. It is, therefore, advisable to ask, what factors should policy focus on to enhance the performance of TFP?

The identification of each source of productivity and its importance in TFP change is, therefore, essential to take appropriate policy measures to improve the productivity of

[1] The Association Agreement with the European Union for the gradual establishment of a free-trade agreement, promoting economic integration and creating a dynamic partnership, constituted in this sense a strategic priority for Tunisia.

domestic firms and thereby their competitive potential. Productivity improvement is, therefore, a golden standard for the firms' competitiveness and constitutes a long-term strategy for economic policy makers.

The main focus of this paper is on change in TFP. Using a panel of Tunisian manufacturing firms observed over the period 1998-2006, this paper aims to decompose TFP growth by constructing a so-called DEA-based Malmquist productivity index, MPI, which measures the productivity change over time. This board of productivity index that has proven itself to be a good tool for measuring productivity change of DMUs allows us to decompose the TFP change into technical efficiency change and technological change and enabling to provide insight on the productive performance of firms. In order to eliminate the problems derived from the DEA estimates relating to the sensitivity of the data to the sample variation and the impossibility of aligning the significativeness of the results, we use the smoothed bootstrap procedure of Simar and Wilson (1999). This method allows to correct and to obtain confidence intervals for the MPI and its two components: efficiency change and technological change.

The remainder of this paper is organized as follows: Section 2 present the methodology adopted to estimate technical efficiency and to decompose the TFP change. The data set and the empirical results are provided and interpreted in Sect. 3, while Sect. 4 concludes with some final observations and policy implications.

2. Productivity measurement using DEA

Data envelopment analysis is a non-parametric linear programming approach to measure the relative efficiency of a homogeneous set of decision making units (DMUs) on the basis of multiple inputs and multiple outputs. Basically this method uses linear programming to build from data a non-parametric frontier. This method consists in determining, from a set of comparable firms, the ones that hold the best practice and thus form the efficiency frontier. The frontier is described by the most efficient firms in the sample and envelope all other observations. The efficiency scores are therefore calculated relatively to the more efficient firms[2].

The empirical analysis starts with the identification of changes in the best-practice (technical) frontier of production in each industry defined as the set of the most efficient

[2] This approach is introduced by Charnes, Cooper and Rhode (1978) in the case of input-oriented efficiency with constant returns to scale and extended by Banker, Charnes and cooper (1984) to the case of output oriented under variable returns to scale hypothesis.

production points in the space of outputs and inputs. Using DEA results, we follow Fare et al. (1994, p. 70) in constructing a geometric mean of two alternative Malmquist productivity indices MPI previously defined by Caves et al. (1982).

To describe the method, we consider a set of n DMUs, in which each consuming K different inputs to produce P different outputs. x_{ik}^{t}, and y_{ip}^{t} denote the k-th input and p-th output respectively of the i-th DMU at any given point in time t. The DEA-based Malmquist index calculation requires two single-period and two mixed-period measures. The two single-period measures are obtained by solving the basic DEA model.

To measure productivity growth we consider two periods, t^1 and t^2. In period t^1 a generic firm produces output y^{t^1} by using input x^{t^1}, whereas in period t^2 quantities are y^{t^2} and x^{t^2}, respectively. Following Shephard (1970), The output-based distance function for a generic firm at period t^1 is defined as :

$$d^{t_1}(x^{t_1}, y^{t_1}) = \inf\{\phi | (x^{t_1}, y^{t_1}/\emptyset) \in \psi^{t_1}\} = [\sup\{\phi | (x^{t_1}, \phi y^{t_1}) \in \psi^{t_1}\}]^{-1} \quad (1)$$

where ψ^{t_1} (x) is the set of all possible levels of the outputs y for the technology prevailing at time t_1 and the input level x. The optimal value of the scalar $\emptyset$ permits us to calculate the maximal proportional expansion of the outputs for given input levels. We note that $d^{t_1}(x^{t_1}, y^{t_1})$ has the meaning of technical efficiency (TE) at the observation point t_1, that is:

$$\hat{d}_i^{t_1}(x_i^{t_1}, y_i^{t_1}) = TE_i^t = 1/_{\emptyset_i^*} \quad (2)$$

The efficiency determines the amount by which produced output can be proportionally increased, while still using the given inputs level. TE_i varies between zero and one ($0 < TE_i \leq 1$, where $TE_i = 1$ means that the ith production unit is fully efficient and operates on the best-practice frontier). Equation (1) refers to the output distance function, and is simply the inverse of the Farrell (1957) output-oriented measure of technical efficiency of the i-th production unit. The same applies to d^{t_2} (x^{t^2}, y^{t^2}).

Computing the MPI requires two additional distance functions to be defined. One measures the maximum proportional change in outputs required to make (x^{t_2}, y^{t_2}) feasible in relation to the technology at t^1, i.e.:

$$d^{t_1}(x^{t_2}, y^{t_2}) = inf\{\phi | (x^{t_2}, y^{t_2}/\emptyset) \in \psi^{t_1}\} = [sup\{\phi | (x^{t_2}, \phi y^{t_2}) \in \psi^{t_1}\}]^{-1} \quad (3)$$

The second refers to the maximum proportional change in output required to make (x^{t^1}, y^{t^1}) feasible in relation to the technology at t^2,:

$$d^{t_2}(x^{t_1}, y^{t_1}) = inf\{\phi|(x^{t_1}, y^{t_1}/\emptyset) \in \psi^{t_2}\} = [sup\{\phi|(x^{t_1}, \phi y^{t_1}) \in \psi^{t_2}\}]^{-1} \quad (4)$$

For both periods t^1 and t^2 the production set, and consequently all distances defined from it are unknown. The four distances which make up a Malmquist index can be estimated via linear programming techniques (see the Web appendix)[3].

According to Fare et al.(1992), The MPI, which measures the productivity change of a particular DMUi, is given as the product of an index measuring changes in technical efficiency ("catching up") and another one capturing the shift in the production frontier ("technical change") as follows:

$$M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1}) = \left[\frac{d^{t_2}(x^{t_2}, y^{t_2})}{d^{t_1}(x^{t_1}, y^{t_1})}\right] \left[\frac{d^{t_1}(x^{t_2}, y^{t_2})\ d^{t_1}(x^{t_1}, y^{t_1})}{d^{t_2}(x^{t_2}, y^{t_2})\ d^{t_2}(x^{t_1}, y^{t_1})}\right]^{\frac{1}{2}} = TEC \times TC \quad (5)$$

The efficiency change component, TEC, shows how much closer (or farther away) a firm gets to the frontier made up of "best practice" firms. This component is greater than, equal to, or less than unity depending on whether the evaluated firm improves, stagnates, or declines. The technical change component TC, measures how much the frontier shifts, and indicates whether the best practice relative to which the evaluated firm is compared is improving, stagnating, or deteriorating. Whatever the case, the index will take a value greater than, equal to, or less than unity; hence technical change is positive, zero, or negative.

Technological change is the development of new products or new technologies that allows methods of production to improve. More specifically, technological change includes both new production processes; called process innovation and the discovery of new product; called product innovation. According to Farrell (1957), technical change is measured through the movement of the production frontier, also called production function corresponding to best practice (best practice Production function). Therefore, all other change in productivity is often interpreted as technical efficiency change due to an

[3] See, for example, Fa¨re et al. (1994), Coelli et al. (1998) and Milana et al (2013) for the exact form of the output-oriented measure of technical efficiency and distance functions derived from the optimization VRS DEA problem.

eventual 'learning by doing', a diffusion of new technological knowledge, improved management practice or to short-term adjustments to external shocks to the firm.

3. Data and empirical results

3.1 The statistical data

We dispose of a sample of Tunisians manufacturing firms observed over the period 1998-2006 wish result in 9107 observations. This data is taken from the national annual survey report on firms (NASRF) carried out by the Tunisian National Institute of Statistics (TNIS). The data cover nearly all firms for different sectors (initially 5000) and which employ at least ten workers.

Table 1: Descriptive Statistics

		Ad-Val	Capital	Nbr-Empl
Agri-Food	*mean*	2253572	7565938	103
	std	5198537	15128633	171,12
Textile, Clothing and Leather	*mean*	9559864	1506943	136
	std	2056742	5899746	159,61
Rubber and Plastic	*mean*	1452386	4749667	79
	std	4342571	1479618	126,5
Chimical industry	*mean*	6174125	19249669	157
	std	27958632	97918746	566,23
Card, Paper and Edition	*mean*	1473665	4268527	72
	std	2662544	8749508	93,87
Mechanical Engineering, Metal, Metallurgic and Electrical	*mean*	1542695	4785891	118
	std	3171467	12632567	169,34
Construction materials, Ceramics and Glass	*mean*	2069574	9854239	110
	std	5014854	26574813	140,93
Miscellaneous	*mean*	498564	974937	58
	std	739214	1596452	67,71
Mean Sample	*mean*	1645712	5077691	125
	std	761547	519037	238,24

Since the data are collected by interviews, the Tunisian NASRF still suffers from a non-response problem. Unfortunately, for the period of 1998–2006, the TNIS does not report any information concerning both the non-response rate of firms and the reasons of non-response. Data are clustered into the following eight major industrial sectors, namely Agri-Food (IAF), Textile, Clothing and Leather (ITCL), Rubber and Plastic (IRP), Chemical industry (ICH), Card, Paper and Edition (ICPE), Mechanical Engineering, Metal, Metallurgic and Electrical (IMME), Construction materials, Ceramics and Glass (ICCV) and Miscellaneous industries. For each firm and sector, we obtained the following data: the number of firms, the number of employees, capital and value added.

We contemplated the manufacturing firm as a one-product organization that produces one output (Value added) with two different inputs (labor and capital). Tables 1 report the main descriptive statistics of our sample where we remark the heterogeneity of firms in the sample in terms of size. In average, these firms employ 125 employees and the majority (75%) employs fewer than 137 employees; it is rather small and medium enterprises in accordance with the Tunisian Industry.

3.2 Empirical results

In order to identify productivity differences between two firms, or one firm over time, we used the output-oriented MPI (see Malmquist, 1953 and Caves et al., 1982). The output-orientated productivity measures focus on the maximum level of outputs that could be produced using a given input vector and a given production technology relative to the observed level of outputs. This is achieved using the output distance functions described in the previews sections. Using this method, two primary issues are addressed in our computation of the MPI growth over the sample period. The first is the measurement of productivity change over the period. The second involves the decomposition of changes in productivity into what are generally referred to as an efficiency change (a 'catching-up' effect) and a technological change (a 'frontier shift' effect). To estimate technical efficiency and MPI we use Value added as a one single output variable (y). Capital and number of employee are used as inputs (x).

A shortcoming of the traditional DEA-based Malmquist Indices is that it does not have any statistical foundation, that is, it lacks statistical precision and does not permit us to determine whether changes in productivity or its two components are real or merely artifacts, since the true production frontiers are unknown and for this reason must be estimated from a finite sample. In fact, the traditional DEA estimator is biased by construction (downward for output orientation) and is affected by the uncertainty resulting from sample variation in the sense that distances to the frontier are underestimated if the best performers in the population are not included in the sample.

Table 2: Bootstrap of efficiency scores

Year		IAF	ICCV	IMME	ICHI	ITCL	IRP	ICPE	Miscel
1998	*Est_Eff*	0,4678	0,5785	**0,5836**	**0,6619**	0,6827	0,4656	0,6024	0,5798
	Bias	0,0152	0,0200	0,0131	0,0263	0,0116	0,0321	0,0156	0,0414
	Bias-Corrected	0,4526	0,5585	0,5705	0,6356	0,6711	0,4335	0,5868	0,5384
	Confidence Interval	[0.4028 0.4557]	[0.5348 0.5711]	[0.5437 0.5784]	[0.6033 0.6521]	[0.5868 0.6789]	[0.4013 0.4452]	[0.5158 0.5922]	[0.4762 0.5414]
2000	*Est_Eff*	0,4893	0,5716	0,5894	0,6772	0,6898	0,4746	0,6213	0,5915
	Bias	0,0096	0,0101	0,0331	0,0402	0,0238	0,0498	0,0113	0,0272
	Bias-Corrected	0,4797	0,5615	0,5563	0,6370	0,6661	0,4248	0,6100	0,5643
	Confidence Interval	[0.4372 0.4821]	[0.5290 0.5677]	[0.5340 0.5622]	[0.5925 0.6435]	[0.6345 0.6713]	[0.3956 0.4528]	[0.5325 0.6187]	[0.5199 0.5798]
2002	*Est_Eff*	0,4461	0,5726	0,5715	0,6848	0,6814	0,4627	0,6173	0,5724
	Bias	0,0135	0,0312	0,0151	0,0133	0,0176	0,0223	0,0129	0,0401
	Bias-Corrected	0,4326	0,5414	0,5564	0,6715	0,6638	0,4404	0,6044	0,5323
	Confidence Interval	[0.3989 0.4390]	[0.5169 0.5569]	[0.5211 0.5638]	[0.6390 0.6781]	[0.6118 0.6760]	[0.4120 0.4531]	[0.5519 0.6108]	[0.4827 0.5511]
2004	*Est_Eff*	0,4853	0,5798	0,5895	0,6829	0,6791	0,4673	0,6294	0,5944
	Bias	0,0132	0,0445	0,0212	0,0198	0,0109	0,0194	0,0199	0,0306
	Bias-Corrected	0,4721	0,5353	0,5583	0,6631	0,6682	0,4479	0,6095	0,5638
	Confidence Interval	[0.4278 0.4792]	[0.5239 0.5590]	[0.5465 0.5682]	[0.6264 0.6697]	[0.6199 0.6729]	[0.4081 0.4586]	[0.5612 0.6151]	[0.5213 0.5797]
2006	*Est_Eff*	0,5116	0,6124	0,6368	0,6864	0,6887	0,4829	0,6413	0,6208
	Bias	0,0461	0,0193	0,0229	0,0372	0,0261	0,0340	0,0263	0,0209
	Bias-Corrected	0,4655	0,5931	0,6139	0,6492	0,6626	0,4489	0,6150	0,5999
	Confidence Interval	[0.4256 0.4829]	[0.5372 0.5992]	[0.6172 0.6266]	[0.6115 0.6523]	[0.6047 0.6673]	[0.4040 0.4635]	[0.5832 0.6246]	[0.5062 0.6125]

To overcome this gap, we use the smoothed bootstrap procedure of Simar and Wilson (1999) to draw bootstrap samples of $\{y, x\}$ and use them to conduct bootstrap inference[4]. This procedure allows us to correct and obtain statistical precision or confidence intervals for the DEA, Malmquist Index and its components[5].

Table 2 summarizes annual mean efficiency for the eight Tunisian manufacturing industries for the years 1998, 2000, 2002, 2004 and 2006 for the sake of brevity[6]. For each year and for each industry we present the original DEA efficiency score (*Est_Eff)*, the bias-corrected estimates (*Bias-Corrected*), the bootstrap bias estimates (*Bias*), and the 95% confidence interval which define the statistical location of the true efficiency. Like Simar and Wilson (1999) we used 2000 bootstrap replications ($B = 2000$). According to these authors this should provide an adequate coverage of the confidence intervals. The smooth boot- strap procedure for productivity was implemented using the FEAR package (Wilson, 2008).

The results indicate that the estimates of technical efficiency differ from the bias-corrected estimates. This later reveals that differences in measured efficiency are of a different magnitude than when original efficiency scores are considered. In some periods this difference (the bias) is quite small. For instance, the average difference was 0.0451. while the bootstrapped DEA estimates lie for every industry inside the confidence interval, it is not the case for the original DEA estimates. Such problems are due to the bias in the original estimates, and it is the main reason why the bootstrapped DEA are preferred to the original estimates. This result reflects the theory behind the construction of the confidence intervals presented by Simar & Wilson (1998b).

Moreover, Table 2 shows that although the manufacturing industries are inefficient in the overall number of years, the efficiency at industry level improved over the period 1998/2006[7]. The average technical efficiency score is around 59% which implies that the firms in our sample can, on average, increase production by 41% using the same levels of inputs in order to match the frontier. The degrees of technical efficiency varies between

---

[4] The smoothing bandwidth parameter (h) was determined by the normal reference rule as suggested by Silverman (1986) for bivariate data and given by Simar and Wilson (1999) $h = (4/5n)^{\frac{1}{6}}$.

[5] All details of the bootstrap inference procedure used in the empirical part of this paper are presented in the online appendix

[6] Results for all years are available from the authors upon request. In this table we report solely the arithmetic mean of efficiency where we are able to construct the confidence level using the central limit theorem (see Wheelock and Wilson, 1999).

[7] Results from this table are very general and help to compare, solely, the performance between industries and not between individual firms.

47,2% in the case of IRP industry and 67,9% and 68,5% in the case of ICHI industry and ITCL industry respectively.

In addition, whatever the sector, there was a slight decline in productivity between 1998 and 2002. This slowdown could be explained by the difficulties associated with the adaptation phase experienced by Tunisian firms following the entry into force of the free trade agreement with the European Union.[8]

Changes in productivity, efficiency and technology are reported in Tables 3, 4, and 5, respectively, for both pairs of consecutive years and the sub-periods 1998/2002, 2002/2006 and the whole sample period 1998/2006. For both sub-periods and the whole sample period, we report arithmetic mean and the geometric mean in the first row and second row respectively. Accordingly, values above unity indicate improvement in productivity, efficiency, or technical change between periods t_1 and t_2, and vice versa.

Table 3: Changes in productivity, consecutive years and sub-periods

period	IAF	ICCV	IMME	ICHI	ITCL	IRP	ICPE	Miscel
1998/99	1,0350***	1,0033	1,0371**	1,0574***	0,9808	1,0169*	0,9611*	1,0238*
1999/00	1,0268***	1,0203*	0,9966	1,0162	0,9907	1,0087	1,0619***	1,0013
2000/01	1,0183	1,0122	1,0072	1,0294*	1,0256	1,0043	1,0671***	0,9999
2001/02	0,8886***	1,0035	0,9423***	0,9574**	0,9432	0,9549**	0,9164***	0,9038
2002/03	1,0663***	0,9738*	1,0213**	1,0013	1,0924***	1,0194	1,032*	1,0513***
2003/04	1,0596***	1,0314*	1,0205	1,0201*	0,9565	1,0034	1,0416**	1,0047
2004/05	1,0569***	1,038*	1,0443***	1,0124	1,024	1,0255*	1,034*	1,0326*
2005/06	1,04**	1,0456**	1,0506**	1,0323*	1,0984***	1,0352*	1,0204	0,9895
1998/02	0,9595**	0,9951	0,9733*	1,0463**	0,9399	0,9902	0,9984	0,9557**
	0,9467	0,9879	0,9611	1,0371	0,9321	0,9748	0,9915	0,9388
2002/06	1,2008***	1,0923***	1,1903***	1,0239*	1,0732**	1,0617**	1,1185***	1,0791***
	1,188	1,0772	1,1823	1,0208	1,0672	1,0572	1,1112	1,0697
1998/06	1,1296***	1,0762***	1,1111***	1,0616***	1,0087	1,0506***	1,1205***	1,0459**
	1,1264	1,0669	1,1052	1,0494	1,0014	1,0409	1,0961	1,0282

(*), (**), and (***): significant differences from unity at 10%, 5%, and 1%, respectively. For the Geometric mean, significance cannot be provided

Table 4 presents the MPI estimates and the statistical testing results of productivity changes for the eight manufacturing sector. For each sub-periods and the whole sample period, we found that Almost all of the estimates are significantly different from unity except ICCV and IRP for the sub-periods 1998/2002 and ITCL for the sub-periods 1998/2002 and the whole sample periods 1998/2006 which are not significantly different from unity.

[8] The growth rate of value added in the manufacturing industries slowed from 6.2% in the period 1987-1994 to 4.8% between 1995-1998 and 4.1% in 1999-2004.

For the whole sample period, the results indicates that the majority of industries experiences an improvement in TFP estimates measured by the MPI. This positive change are due to a significant improvement in productivity between 2002 and 2006.

Given that the MPI is a multiplicative composite of efficiency change and technological change, the principal component of productivity improvements can be ascertained by comparing the values of the efficiency change and technological change indexes. We can see that the aggregate TFP increased in average by 7.55% over the period 1998/2006. This result suggests that by 2006, Tunisians manufacturing firms were providing, on average, 7.55% as much output per unit of input as in 1998. It seems that the coexistence of improvement in technical efficiency and the positive shift in frontier have contributed to enhance productivity. Particularly, this performance was due mainly to technical efficiency change (5.77%) and a relatively low technological change (1,67%).

Table 4: Efficiency change, consecutive years and sub-periods

period	IAF	ICCV	IMME	ICHI	ITCL	IRP	ICPE	Miscel
1998/99	1,025*	0,9827	1,0046	1,0195***	1,0072	1,0152*	1,0051	1,0204*
1999/00	1,0204**	1,0055	1,0053*	1,0036	1,0032	1,004	1,0261**	0,9998
2000/01	1,0108	1,0033	1,0151*	1,0065	0,999	1,0059	1,0129***	1,0139**
2001/02	0,9019***	0,9984	0,9552**	1,0047	0,9888	0,9692**	0,9809**	0,9545
2002/03	1,0509***	1,0026	1,0199**	0,992	1,0048	1,0102	1,007	1,0363**
2003/04	1,0352*	1,0099	1,0113***	1,0053	0,9918	0,9998	1,0125*	1,002
2004/05	1,0332*	1,0281**	1,0383***	0,9956	1,0112**	1,015***	1,0099	1,0355***
2005/06	1,0203	1,0273**	1,0404**	1,0096	1,0029	1,0181**	1,009	1,0086
1998/02	0,9536**	0,9898	0,9793*	1,0346**	0,9981	0,9938	1,0247*	0,9872*
	0.9414	0.9820	0.9712	1.0169	0.9917	0.9835	1.0211	0.9748
2002/06	1,1468***	1,0695**	1,1143***	1,0023	1,0107*	1,0437**	1,0389***	1,0846**
	1.1391	1.0566	1.1090	1.0022	1.0090	1.0408	1.0344	1.0792
1998/06	1,0936***	1,0586***	1,0912***	1,037**	1,0088*	1,0372***	1,0646***	1,0707***
	1.0921	1.0517	1.0875	1.026	1.0041	1.0308	1.0433	1.0568

(*), (**), and (***): significant differences from unity at 10%, 5%, and 1%, respectively. For the Geometric mean, significance cannot be provided.

Besides the ITCL industries which recorded a non-significant TFP change, the other industries have realized gains in TFP. The greatest increase in TFP has been registered in IAF (12.64%), IMME (10.52%), ICPE (9.61%). These industries have had an improvement in both technical efficiency and technical change. It seems that ICPE is the most innovative with a technical change of about 5.1%. Positive but smaller changes in TFP have been observed in Miscel industry (2.82 %). For this industry, improvement in technical efficiency has offset the apparent negative shift in the frontier.

Across industries, TFP growth has been highly heterogeneous for the first sub periods 1998/2002. Although IAF, IMME and Miscel industries have experienced a decrease in TFP, the ICHI and ICPE are the only industries that experienced gains in TFP due to coexistence of a positive change in technical efficiency and a positive shit in the production frontier. For the other industries, MPI are not significantly different from unity. On the other hand, during the second sub periods 2002/2006 all industries have experienced an improvement in their performance indicators which contributed to enhance the aggregate TFP change. This significant improvement have contributed to a positive TFP change over the hole sample periods for almost all industries. Productivity growth is especially high during the 2002/2006 period, in which the rate of productivity growth was 7.91%, due to increases in periods 2002/2003, 2003/2004, 2004/2005 and 2005/2006 of 3.22%, 1.72%, 3.35% and 4%, respectively.

Table 5: Technological change, consecutive years and sub-periods

period	IAF	ICCV	IMME	ICHI	ITCL	IRP	ICPE	Miscel
1998/99	1,0098	1,021**	1,0324***	1,0372***	0,9738**	1,0017	0,9562**	1,0033
1999/00	1,0063	1,0147*	0,9913	1,0126*	0,9875*	1,0047	1,0349**	1,0015
2000/01	1,0074	1,0089	0,9922	1,0228**	1,0266**	0,9984	1,0535***	0,9862
2001/02	0,9852	1,0051	0,9865*	0,9529***	0,9539	0,9852	0,9342***	0,9469**
2002/03	1,0147	0,9713**	1,0014	1,0094	1,0872***	1,0091	1,0248*	1,0145*
2003/04	1,0236***	1,0213**	1,0091	1,0147*	0,9644*	1,0036	1,0287**	1,0027
2004/05	1,0229***	1,0096	1,0058	1,0169*	1,0127	1,0103	1,0239	0,9972
2005/06	1,0193*	1,0178*	1,0098	1,0225*	1,0952***	1,0168*	1,0113	0,9811
1998/02	1,0062	1,0054	0,9939	1,0113*	0,9412**	0,9964	0,9743	0,9681**
	1,0056	1,0051	0,9896	1,0100	0,9399	0,9912	0,9710	0,9631
2002/06	1,0471***	1,0213**	1,0682***	1,0216*	1,0618***	1,0172*	1,0766***	0,9949
	1,0429	1,0195	1,0661	1,0186	1,0577	1,0158	1,0742	0,9912
1998/06	1,0329***	1,0166*	1,0182*	1,0237***	0,9999	1,0129*	1,0525***	0,9768**
	1,0310	1,0145	1,0163	1,0228	0,9973	1,0098	1,0506	0,9729

(*), (**), and (***): significant differences from unity at 10%, 5%, and 1%, respectively. For the Geometric mean, significance cannot be provided.

4. Conclusion

From a sample of Tunisian manufacturing firms observed over the period 1998-2006 the aim of this paper was to decompose TFP change to find the most contributive source to productivity gains. For this purpose, we have proposed to estimate the DEA-based MPI which measures the productivity change over time and allows us to decompose the TFP change in technical efficiency change and technical change and enabling to give insight on the productive performance of firms. We used the smoothed bootstrap method proposed by Simar and Wilson (1999) to give more insight concerning the significance of the observed changes in TFP and its components.

Results show that the average technical efficiency score is around 59% which implies that the firms in our sample can, on average, increase production by 41% using the same levels of inputs in order to match the frontier. The technical efficiency score varies between 47,2% in the case of IRP industry and 68,5% in the case of ITCL industry.

For the whole sample period, the results indicate that the majority of industries experience an improvement in TFP estimates. A 7.55% increase in aggregate TFP between 1998 and 2006 was due mainly to technical efficiency change (5.77%) and a relatively low technological change (1,67%). Different conclusions could be drawn from the first sub-period 1998/2002. Although IAF, IMME and Miscel industries have experienced a decrease in TFP, only the Chimical industry experienced gains in TFP. For the other industries, MPI are not significantly different from one.

The realization of the growth objective in Tunisia is based on the challenge of improving the contribution of TFP. Such an objective requires enhancement of human resources through the establishment of an adequate education and training system to support the uptake of technologies and the creation of an environment conducive to better use of resources. The boosting investment in human capital to increase its contribution to growth and thus devote its leading role in the development process. Likewise, this objective underlies better economic performance and greater integration in the new economy with all that it entails as use of new information technologies and communication and support for research and the innovation to diversify the product and improve its competitiveness.

finely, the existence of large productivity gaps across sectors suggest that reallocation of resources from low productivity sectors to high productivity sectors can be an important growth factor. In fact, in many countries with high growth, especially in Asia, the reallocation of workers across sectors contributed positively to growth over the last twenty years (McMillan and Rodrik 2011).

References

Banker, R.D., A. Charnes and W.W. Cooper (1984) "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis" *Management Science*, 30, 1078-1092.

Charnes, A., W.W. Cooper and E. Rhodes (1978) "Measuring the efficiency of decision making units "*European Journal of Operational Research* 2, 429-444.

Coelli, T., D.S.P. Rao and G.E. Battese (1998) "*An Introduction to Efficiency and Productivity Analysis"*, Kluwer Academic Publisher, Boston.

Caves, D.W., L.R. Christensen and W.E. Diewert (1982) "The economic theory of index numbers and the measurement of input, output and productivity" *Econometrica*, 50(6), 1393-1414.

Färe, R.S., S. Grosskopf, B. Lindgren and P. Roos (1992) "Productivity change in Swedish pharmacies 1980-1989: a nonparametric Malmquist approach" *Journal of Productivity Analysis*, 3, 85-102.

Farrell, M.J. (1957) "The measurement of productive efficiency", *Journal of the Royal Statistical Society*, 120, 253-290.

Gitto, S. and P. Mancuso (2012) "Bootstrapping the Malmquist indexes for Italian airports", *International Journal of Production Economics*, 135(1), 403-411.

Krugman, P. (2005) "Second winds for industrial regions?" in *New wealth for old nations, Scotland's economic prospects* by D. Coyle, W. Alexander and B. Ashcroft (eds) Princeton Eds., University Press, Princeton, pp 35-47

Malmquist, S. (1953) "Index numbers and indifference surfaces", *Trabajos de Estadistica,* 4, 209-241

Milana, C., Nascia, L. and A. Zeli (2013) "Decomposing multifactor productivity in Italy from 1998 to 2004: evidence from large firms and SMEs using DEA", *Journal of Productivity Analysis*, 40(1), 99-109.

Solow, R.M. (1957) "Technical change and the aggregate production function", *The review of Economics and Statistics*, 312-320.

Shephard, R.W. (1970) "Theory of Cost and Production Functions". In *Princeton, Princeton University Press*.

Silerman, B.W. (1986) "Density estimation or statistics and data analysis" In *Chapman and Hall, London*.

Simar, L and P. Wilson (1999) "Estimating and bootstrapping Malmquist indices". *European Journal of Operational Research*, *115*(3), 459-471.

Simar, L and P. Wilson (1999) "Of course we can bootstrap DEA scores! But does it mean anything? Logic trumps wishful thinking", *Journal of Productivity Analysis*, *11*(1), 93-97.

Simar, L and P. Wilson (2000) "Statistical inference in nonparametric frontier models: The state of the art", *Journal of productivity analysis*, *13*(1), 49-78.

Solow, R.M. (1957) "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, 39(3), 312-320.

Wheelock, D.C and P.W. Wilson (1999) "Technical progress, inefficiency, and productivity change in US banking", *Journal of Money, Credit, and Banking*, 212-234.

Wilson, P.W. (2008) "FEAR: a software package for frontier efficiency analysis with R", *Socio-Economic Planning Sciences*, 42 (4), 247–254.