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ASSESSING A NEW DECOMPOSITION OF THE SHORT AND LONG RUN COST EFFICIENCY FRONTIERS IN THE TUNISIAN MANUFACTURING SECTOR

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Abstract: *This paper analyzes the efficiency of the Tunisian manufacture sector using non-convex frontier methods. More specifically, it analyzes the total cost inefficiency and proposes its new decomposition into three additive components: short-run variable cost inefficiency; capacity utilization of fixed inputs, and scale inefficiency. The last two components correspond to the long-run cost efficiency concept. This exercise is applied to all the data in the Tunisian manufacturing industry. The results confirm the existence of significant cost inefficiency coefficients related to both long- and short-run analyses.*

Keywords: Data envelopment analysis, capacity utilization, non-convex frontier, efficiency

INTRODUCTION

The main objective of this work is to conduct an assessment of the nonparametric cost efficiency of the Tunisian manufacturing industry and propose a new additive decomposition of the cost frontier deviation. As this is well known, the non-parametric cost efficiency analysis determines the cost excess of non-frontier units. In the traditional non-parametric cost frontier analysis (Fare, Grosskopf and Lovell, 1994), the excess cost is decomposed into three components: the pure technical efficiency coefficient, the allocative efficiency coefficient and the scale efficiency coefficient. This paper proposes an alternative decomposition regarding Giménez and Prior (2007) which introduces concepts of long- and short-run efficiency. More specifically, this proposal decomposes the total cost efficiency deviation into three components: short-run variable cost efficiency, capacity utilisation of fixed inputs and scale efficiency. There is a reason to postpone the introduction of technical and allocative components after verification of the capacity utilization of fixed inputs. When some inputs are fixed, this reasonable to reduce the short-run variable cost into its allocative and technical components, but not the long-run total cost efficiency deviation, as does the traditional decomposition.

Regarding the type of the frontier analysis, due to budgetary constraints faced by local governments, we propose non-convex cost frontiers instead of convex production frontiers. The decision was made after considering the evidence that non-convex technology can be a plausible hypothesis in the industrial sector (Balaguer-Coll-Tortosa Ausina and Prior, 2007).

There are positive and negative aspects for the decision to conduct a comprehensive analysis. On the positive side, we obtain a specific efficiency coefficient representing the global assessment of the various activities provided by each sector. In addition, even though it may appear paradoxical, when evaluating individual services, the results obtained could indeed be more controversial. For

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example, if information about the inputs is not directly available, it is necessary to use arbitrary cost-accounting allocation criteria to estimate the input consumption of a specific sector. The negative aspect of the decision is the problem of selecting representative variables of the various activities offered by the manufacturing industry.

To summarize, the analysis of the specific manufacturing services provides an acceptable assessment of the output variables, but it is extremely difficult to determine the specific inputs consumed. The alternative option, however, has weaknesses on the output side. In fact, this is already a very well known dilemma regarding the evaluation of industrial organizations.

The remainder of this paper is organized as follows. The first section presents the proposal for the evaluation of the cost frontier. The second section is a detailed description of non-convex programs for the cost frontier estimation. The last section is devoted to the presentation of the variables and the main results. In the last part, we present a summary of the analysis.

LITERATURE REVIEW

Cost efficiency frontier: the proposal of a new decomposition

As has been well established, when inefficiency is determined, the decision on how to achieve the best practice frontier is conditioned by the objectives of the units being assessed and the degree of control over the variables. Therefore, when the inputs are fixed and the market is growing, it seems quite reasonable to conduct an output orientation. In contrast, when production is exogenous, an input orientation seems more appropriate. It may also be the case that, for practical purposes, the most recurrent choice to avoid inefficiency is to mix the output and the input orientations, or using a more technical nomenclature, to take the direction of the "directional distance functions".[3] In our specific case study, local authorities take the outputs as exogenous, but they have the ability to control inputs, especially in the long run. Thus, the cost orientation seems an appropriate choice when the analysis is orientated towards the assessment of the overall efficiency of the sector.

Let's take the following notations, and assume that for *J* units, there are *L* inputs producing *I* outputs. Hence, each sector *k* uses an input vector $x_k = (x_{k1},...,x_{kl},...,x_{kL}) \in IR_+^L$ to produce an output vector $y_k = (y_{k1},...,y_{kl},...,y_{kL}) \in IR_+^I$. Production technology is defined by the set of feasible input and output vectors:

$$F = \{(x, y) \mid x \text{ can produce } y\} \tag{1}$$

It is also useful to consider the input set associated with this technology. For a given output vector y_k, the input set denotes all the input vectors x capable of producing the output vector:

$$L(y_k) = \{x \mid (x, y_k) \in F\} \tag{2}$$

The next theoretical building block is the measurement of cost efficiency. To this end, we denote the observed total cost of producing y_k as $TC_k(y_k) = w_k x_k$ where $w_k = (w_{k1}, \cdots, w_{kl}, \cdots, w_{kL}) \in IR_+^L$ is the vector of input prices. Since we do not have information concerning input prices, from now on the cost notation $TC_k(y_k)$ is used.

[3] See Färe and Grosskopf (2000).

From the long-term perspective, inefficient municipalities should reduce $TC_k(y_k)$ in order to obtain the minimum total cost of producing y_k, $TC_{lr}(y_k)$.

From the short-term perspective, there are fixed costs, $FC_k(y_k)$, and variable costs, $VC_k(y_k)$, having then:

$$TC_k(y_k) = FC_k(y_k) + VC_k(y_k) \tag{3}$$

In the short term, inefficient units can only reduce the observed variable costs, $VC_k(y_k)$, in order to produce y_k at the minimum variable costs, $VC_{sr}(y_k)$, given the endowment of fixed inputs, $FC_k(y_k)$.

With the cost structure defined, our proposition quantifies the difference, in absolute terms, between the observed total costs of sector k, $TC_k(y_k)$, and the long-run minimum total cost frontier, $TC_{lr}(y_k)$, assuming constant-returns-to-scale technology. The difference between the observed and long-run frontier costs yields the *total cost deviation*, TCD_k, formulated as:

$$TCD_k(y_k) = TC_k(y_k) - TC_{lr}(y_k) \tag{4}$$

As indicated in the introduction, TCD_k can be reduced into additive components corresponding to the short-term variable cost deviation, *SRVCD*, and the long-term total cost deviation, *LRTCD*, reflecting how inefficient costs are affected by: (a) the short-term efficient variable cost; (b) the efficient capacity utilisation of fixed inputs; and (c) the scale efficiency. That is, (b) and (c) are parts of the long-run total cost deviation.

The *short-term variable cost deviation* can be attributed to the excessive level of variable cost, given the fixed costs structure and the observed output level. Mathematically, this deviation can be expressed as:

$$\begin{aligned} SRVCD_k &= TC_k(y_k) - TC_{sr}(y_k) \\ &= [FC_k(y_k) + VC_k(y_k)] - [FC_k(y_k) + VC_{sr}(y_k)] = VC_k(y_k) - VC_{sr}(y_k) \end{aligned} \tag{5}$$

where $VC_{sr}(y_k)$ is the minimum variable cost required to produce output y_k. However, given the observed level of exogenous fixed inputs, $FC_k(y_k)$, it is impossible to modify the short run costs. As defined in the short run, $VC_{sr}(y_k)$ is determined in the variable-returns-to-scale assumption.

The following deviation is the so-called *capacity utilisation deviation*, which quantifies the excess arising from a non-optimal structure of fixed inputs given output level y_k:

$$CUD_k = TC_{ct}(y_k) - TC_{cap}(y_k) \tag{6}$$

where $TC_{cap}(y_k)$ is the frontier efficient total cost for sector k, after adjusting the fixed and variable inputs so that the total costs are minimal. Verbalising, in the variable-returns-to-scale framework, $TC_{sr}(y_k)$ is determined assuming $FC_k(y_k)$ to be exogenous, while $TC_{cap}(y_k)$ assumes $FC_k(y_k)$ to be endogenous. This is a wise way in which to model the cost excess produced by the fixed state of some inputs.

Finally, the *scale deviation*, *SD*, is obtained by comparing the minimal cost frontier at the optimal capacity of council k, $TC_{cap}(y_k)$, with the long-term minimum total cost required to produce y_k, $TC_{lr}(yk)$, assuming constant returns-to-scale technology:

$$SD_k = TC_{cap}(y_k) - TC_{lr}(y_k) \tag{7}$$

Figure ***1*** depicts the case of a hypothetical total cost frontier and the three previously outlined factors that lead to inefficiency. In this figure, the deviations can be calculated following the cost components defined:

$$\begin{aligned} TCD_k &= TC_{cap}(y_k) - TC_{lr}(y_k) = SRVCD_k + LRTCD_k = SRVCD_k + CUD_k + SD_k \\ &= [VC_k(y_k) - VC_{sr}(y_k)] + [TC_{sr}(y_k) - TC_{cap}(y_k)] + [TC_{cap}(y_k) - TC_{lr}(y_k)] \end{aligned} \tag{8}$$

SRVCD appears when the observed and short-run frontier variable costs are compared, without modifying the observed fixed costs. *CUD* includes the cost excess due to the non-optimal level of fixed inputs. Finally, *SD* depends on the cost differences between constant and variable returns to scale, given the output level y_k. It should be noted that figure 1 refers to a particular case in which all deviations are positive. Nevertheless, the proposed decomposition is also applicable in other situations with null values for some deviations (say, when the fixed inputs are used at the optimal level or when there is no scale inefficiency). The mathematical programs needed to calculate each element of the proposed decomposition are presented in the next section.

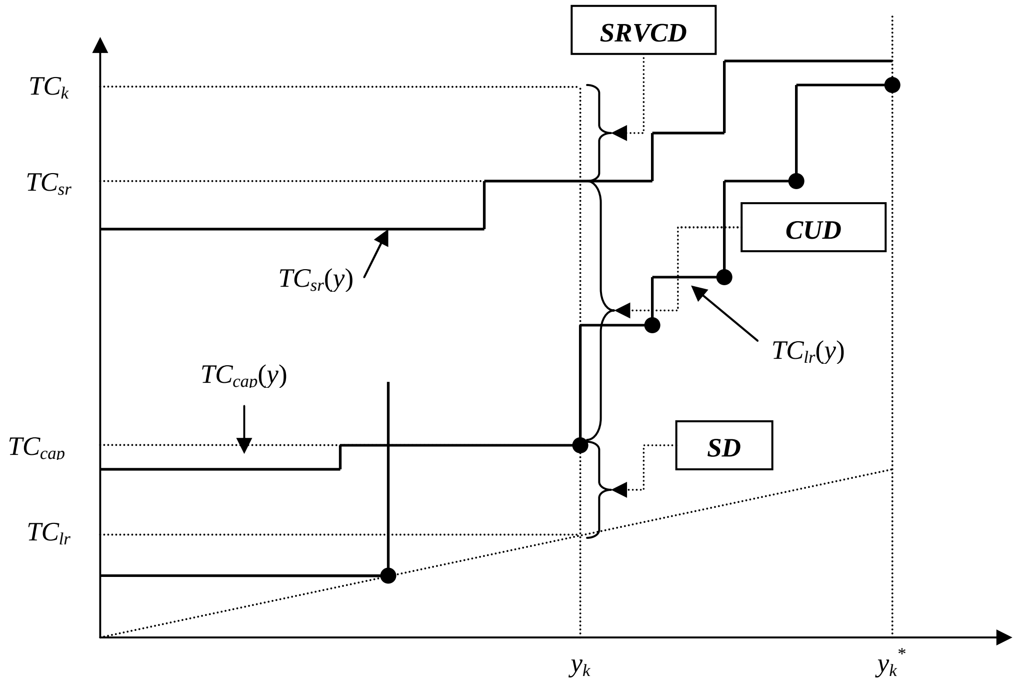

Figure 1 ***Hypothetical structure of total costs and proposed decomposition of the long-run total cost deviation***

Source : Giménez and Prior, 2007, p. 127.

Formulation of non-convex programs for the cost frontier evaluation

The decomposition presented in the above section requires a definition of the capacity utilisation concept. An initial problem is that there is still no complete consensus on the way to measure the capacity utilisation rate and its effects on costs. In reviewing the literature, there are two main approaches to the concept of capacity utilisation:

• *capacity as the maximum level of production in physical terms* (potential level of production that entirely uses the existing capacity);

• *capacity as the desirable level of production in economic terms* (optimum amount of production at the lowest point of the average total cost).

These two notions of capacity coincide when the reference technology exhibits increasing returns to scale. A problem arises when the returns to scale have only a local significance and the average cost curves are shaped in the well-known 'U' form. In this situation, the average total cost of the first approach is always higher than that of the second. This is the reason why, from an economic point of view, we advocate the second approach as a way of guaranteeing, under all circumstances, the optimal cost minimisation reference.[4]

To define the notion of the capacity employed, it is necessary to pay attention to the programs that must be resolved. For the sake of brevity, programs are introduced in the same order as the breakdowns presented in the section above. In order to determine the short-run variable cost frontier, there is a proposal made by Primont (1993), in agreement with previous work by Hausman and Neufeld (1991), formulating the following linear program:

$$VC_{sr}\left(y_k, CF_k\right) = \min_{CV, z_j} VC$$

$$s.c.\ VC - \sum_{j=1}^{J} z_j.VC_j \geq 0;\ FC_k - \sum_{j=1}^{J} z_j.FC_j \geq 0; \sum_{j=1}^{J} z_j.y_{ij} - y_{ik} \geq 0;\ i = 1,...,I,\ \sum_{j=1}^{J} z_j = 1;\ CV, z_j \geq 0. \tag{9}$$

Program (***9***) refers to the variable cost minimisation where the fixed costs are exogenous. There are similar versions of this program defined by other nonparametric frontier models: Banker and Morey (1986) use a similar formulation when computing technical efficiency and Färe, Grosskopf and Lee (1990) introduce the same restriction of fixed inputs when defining a non-parametric restricted profit maximisation.

Program (***9***) postulates a convex technology under which the frontier is composed of real observations and their linear combinations. In other words, every convex combination of feasible production plans is also feasible. The problem is that it is not granted a priori that the convexity postulate is the most suitable assumption and it may be worth contemplating other technological references. If convexity is not postulated, we can adopt the so-called non-convex reference technology defined by the FDH (Free Disposal Hull Frontier)[5]. Among other advantages, it has been demonstrated that when the true technology is convex, the FDH estimator converges to the true estimator. In contrast, when the true technology is non-convex, the convex estimator causes a specification error.[6] We also have evidence that non-convexity can be the appropriate technology in manufacturing (Vanden Eeckaut, Tulkens and Jamar, 1993; Balaguer-Coll, Prior and Tortosa-Ausina, 2007). Further rationale on the advantages of FDH can be found in Briec, Kerstens and Vanden Eeckaut (2004).

As suggested by Tulkens (1993), it is straightforward to relate *FDH* models to the convex *VRS* (Variable Returns to Scale), since only one new restriction must be included in the mathematical programming problem (***9***), namely, $z_j \in \{0,1\},\ j = 1,...,J$. Having taken this into account, the non-convex version of program (***9***) is:

[4] More details of this discussion can be found in Prior (2003).
[5] See Deprins, Simar and Tulkens (1984).
[6] See Park, Simar and Weiner (2000) and Simar and Wilson (2000).

$$VC_{ct}(y_k, FC_k) = \min_{CV, z_j} VC$$
$$s.c.\ VC - \sum_{j=1}^{J} z_j.VC_j \geq 0;\ FC_k - \sum_{j=1}^{J} z_j.FC_j \geq 0; \sum_{j=1}^{J} z_j.y_{ij} - y_{ik} \geq 0, i = 1,...,I;$$
$$\sum_{j=1}^{J} z_j = 1; z_j \in \{0,1\}, j = 1,..., J; VC \geq 0. \quad \textbf{\textit{(10)}}$$

Continuing with the remaining variables needed in order to apply the additive decomposition, the capacity cost frontier operates with the notion of total costs ($TC_k = FC_k + VC_k$) being adjustable to produce the output level at the minimum total costs under a variable-returns-to-scale technology assumption. It is deduced from the following program:

$$TC_{cap}(y_k) = \min_{TC, z_j} TC$$
$$s.c.\ TC - \sum_{j=1}^{J} z_j.TC_j \geq 0; \sum_{j=1}^{J} z_j.y_{ij} - y_{ik} \geq 0, i = 1,..., I; \sum_{j=1}^{J} z_j = 1; z_j \in \{0,1\}, j = 1,..., J; TC \geq 0. \quad \textbf{\textit{(11)}}$$

Finally, following Giménez (2004) and Giménez and Prior (2007), the long-run minimal cost frontier (assuming constant returns to scale) derives from the optimal solution of the following program:

$$TC_{lt}(y_k) = \min_{TC, z_j, \lambda_j, B} TC$$
$$s.c.\ TC - \sum_{j=1}^{J} z_j.TC_j \geq 0;\ \sum_{j=1}^{J} z_j.y_{ij} - y_{ik} \geq 0, i = 1,..., I; \sum_{j=1}^{J} \lambda_j = 1; \lambda_j \in \{0,1\}, j = 1,..., J;$$
$$\lambda_j.B \geq z_j, j = 1,..., J; TC, z_j, B \geq 0, B \to \infty. \quad \textbf{\textit{(12)}}$$

Empirical application to Tunisian manufacturing

In this section, we analyze the efficiency of the Tunisian manufacturing sector using non-convex frontier and measure the capacity utilization of the quasi-fixed factors. In addition, we decompose the total cost inefficiency of three additive components: the short-run variable cost inefficiency; capacity utilization of fixed inputs, and scale inefficiency. The empirical study will be developed on data from the global manufacturing industry (MI) and its six sectors such as: Agricultural & Food Industries (AFI); Building Materials, Ceramics & Glass (BMCG); Mechanical & Electric Industries (MEI); Chemical Industries (CHI); Textiles, Clothing & Leather (TCL) and Various Manufacturing Industries (VMI).

In fact, the selection of data required to assess the efficiency of the manufacturing sector is still a controversial task. It is difficult to measure the inputs and, more specifically, the outputs of these sectors due to the heterogeneity within them. It is important to define, first, the objectives and, secondly, the problems of measuring the outputs themselves. Given the objectives of this study, the limitations of the database can cause some criticism critical for the selected variables.

METHODLOGY

Data and variables

We use annual time series for the Tunisian manufacturing sector built by ***TICQS***[7] for the period 1961-2010. We consider a production technology of a single output and three inputs. The output is measured by the quantity of gross production. The inputs are labor, capital and energy. All the inputs are measured by the appropriate quantities. We treat the capital as the only quasi-fixed input in the short run. The price indices of individual inputs were used as relevant input prices in cost minimizing problems. We suppose that technology exhibits, in the long run, constant returns to scale. In addition, technical progress is assumed to be non-regressive. Therefore, all the combinations of input-output from previous years as well as the current input-output set are considered feasible during the same year. Therefore, in effect, we consider a boundary sequence.

Our selection of inputs is based on variables reflecting the manufacturing budgetary costs. These are real values rather than used forecast expenditures, because forecasts usually underestimate expenditure and overestimate income. Regarding the classification of costs in the short run, the labor and energy costs are variable factors. The only fixed cost is presented by the capital stock. The selection of the output is based on the gross domestic product (GDP). In summary, the definition of input and output variables is as follows:

VC_1: The labor expenditure = Mass Salary (MS);

VC_2: The energy expenditure = Energy Value (EV);

FC: The aggregate capital expenditure;

Y: Gross Domestic Product.

Table 1 ***Descriptive statistics of the variables (T=50)***[8]

	Minimum	Maximum	Average	SD	R	r
Y	180.9	4220.9	1717.3	1296.8	1593.6%	5.9%
VC1	21.6	4499.1	1041.6	1268.2	20729.2%	11.5%
VC2	146.3	1134.8	472.4	277.8	675.6%	4.3%
TVC	167.9	5633.9	1514.0	1538.7	3255.4%	7.4%
TFC	22.9	23304.3	6771.9	7129.7	101808.1%	15.2%
TC	190.8	28938.1	8285.8	8642.4	15068.8%	10.8%

A summary of the descriptive statistics of the variables are presented in Table ***1***. The data correspond to the period from 1961 to 2010 for manufacturing as a whole. We recorded a strong growth of costs in particular fixed costs.

RESULTS AND INTERPRATION

After applying the programs described in the second section, we determine the decomposition in the first section. Table ***2*** shows the mean values of cost differences.

For the Inefficient years, the long-run total cost deviation (*LRTCD*) varies between 11% and 54% of actual expenditure. It comes mainly from the scale difference (*SD*) and capacity utilization deviation (*CUD*) according to the nature of the sector in question. Suboptimal fixed capacity utilisation (*CUD*) occurs in the sectors AFI, BMCG, MEI and CHI. Moreover, inefficiency in the

[7] Tunisian Institute of Competitiveness and Quantitative Studies.
[8] SD: Standard Deviation, R: Overall growth rate, r: Average annual growth rate.

capital cost is not significant at the global level. The deviation related to variable factors in the short run (*SRVCD*) rises up to 9% of the total costs, but is not defined for MI, AFI, TCL and VMI. In terms of overall costs, the cost excess is 19%. Of this total, no more than 0% can be corrected in the short run, most of it, that is 19% depends almost entirely on the scale of the industry.

Table 2 ***Average cost deviations for inefficient years by sector***

	Designations	MI	AFI	BMCG	MEI	CHI	TCL	VMI
SRVCD	***Number of inefficient Years***	0	0	35	23	36	0	0
	Average value of the deviations in relation to the inefficient years	-	-	4.89%	7.62%	8.55%	-	-
	Average value of the deviations in relation to the total cost	0.00%	0.00%	4.84%	0.36%	8.35%	0.00%	0.00%
CUD	***Number of inefficient Years***	0	10	50	30	50	0	0
	Average value of the deviations in relation to the inefficient years	-	12.76 %	47.63 %	13.98 %	28.19 %	-	-
	Average value of the deviations in relation to the total cost	0.00%	5.25%	47.63 %	2.09%	28.19 %	0.00%	0.00%
SD	***Number of inefficient Years***	48	17	50	42	50	23	31
	Average value of the deviations in relation to the inefficient years	20.28 %	8.86%	6.33%	24.14 %	13.44 %	13.09 %	10.99 %
	Average value of the deviations in relation to the total cost	18.58 %	6.15%	6.33%	13.23 %	13.44 %	4.60%	2.88%
LRTCD	***Number of inefficient Years***	48	12	50	42	50	23	31
	Average value of the deviations in relation to the inefficient years	20.28 %	18.76 %	53.96 %	27.94 %	41.63 %	13.09 %	10.99 %
	Average value of the deviations in relation to the total cost	18.58 %	11.40 %	53.96 %	15.32 %	41.63 %	4.60%	2.88%

Now, we will focus on the factors that explain the inefficiencies found. At first, this can be done by analyzing the results based on two criteria: the size of the sectors relating to the total cost and to the average level of production. Table ***3*** presents the descriptive analysis of deviations by sector. The analysis of the overall structure is in the first column (MI) of the table.

Table 3 ***Descriptive analysis of cost deviations classified by sector (%)***

Designations	MI	AFI	BMCG	MEI	CHI	TCL	VMI
Size % total cost	100	18,30	20,46	16,47	15,33	19,84	9,72
Size % production	100	19,20	10,54	23,02	8,73	26,88	14,69

SRVCD	***Minimum***	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Maximum	0,00	0,00	37,58	27,41	57,57	0,00	0,00
	Average	0,00	0,00	5,58	5,17	11,27	0,00	0,00
	Standard Deviation	0,00	0,00	7,20	7,20	14,38	0,00	0,00
CUD	***Minimum***	0,00	0,00	8,42	0,00	1,33	0,00	0,00
	Maximum	0,00	23,60	74,60	42,26	89,00	0,00	0,00
	Average	0,00	2,65	50,88	9,73	42,23	0,00	0,00
	Standard Deviation	0,00	6,09	11,67	11,23	24,68	0,00	0,00
SD	***Minimum***	0,00	0,00	0,20	0,00	0,90	0,00	0,00
	Maximum	79,60	34,80	56,80	66,60	34,30	85,50	82,80
	Average	40,32	4,63	17,07	30,57	18,26	20,04	27,60
	Standard Deviation	25,89	8,63	16,17	20,46	10,94	27,63	30,54
LRTCD	***Minimum***	0,00	0,00	42,08	0,00	21,12	0,00	0,00
	Maximum	79,60	34,80	96,00	80,05	98,60	85,50	82,80
	Average	40,32	4,60	67,48	40,30	59,56	20,04	27,60
	Standard Deviation	25,89	9,83	17,69	26,26	26,71	27,63	30,54

For the global manufacturing industry, the average value of *LRTCD* is 40.3% and that for *SRVCD* is 0%. At the sector level, the average values of *LRTCD* vary between 20% and 67.5% and those for *SRVCD* vary between 0% and 11.3%. By analysing by cost size, it appears that *SRVCD* decreases (indicating better efficiency) as the size increases. These results suggest that short-run variable cost inefficiency is more pronounced in small sizes (ICH and MCCV), while larger sectors are less dispersed with regard to their respective short run variable cost frontier. In other words, larger sectors have the advantage of being able to exercise greater control over the variable costs. Besides, the reasons for this may well be that larger sectors have comparatively more production values. The implications of these results reflect the common sense: if better production system exists, there will be more efficient execution of operating expenses.

Turning our attention to the long run, the situation remains the same and the major sectors have a better performance. This deviation highlights to big sectors being closer to their specific optimal scale than small sectors. In summary, both short- and long-term cost deviations indicate that efficiency problems affect small sectors. However, we should notice two points before confirming more conclusive results: (1) the number of sectors in each group varies, and (2) we do not, still know the extent to which the efficiency differences are in efficiency statistically significant.

Paying exclusive attention to the characteristics of efficient sectors, it seems that there is a total of 3 sectors (AFI, TCL and VMI) the nearest to the long run frontier. According to the total cost (AFI, BMCG and TCL are large in size, MEI and CHI are medium in size and **VMI** is small. The average size of the efficient sectors is 1322 TMD (1618.5 TMD for the big ones, 1317.4 TMD for the medium-sized ones and 805.7 TMD for the small). According to the total production, Table ***3*** reflects the fact that the sectors where the average production is high (TCL, MEI and AFI) (average production exceeds 390.9 TMD) generally have the biggest cost excess (more than 20 % of observed costs). In other sectors, the differences seem not be very significant.

It is interesting to see the statistical significance of the factors affecting the deviations found. To do so, we apply a multiple regression analysis defining *TCD* as the dependent variable and several environmental factors as independent variables:

• Income (Rev): dummy variable to express the level of the capital average productivity in the sector (three groups: low (1), medium (2) and high productivity (3))

• Commerce (Com): index capturing importance of commerce in the sector (openness = [Export + Import] / GDP);

• Labor (L): total number of workers;

• Consumption (Cons): the level of intermediate consumption.

From Figure 2 of the evolution of the capital average productivity, we note that the six sectors are grouped into three groups: BMCG and CHI are small, MEI and VMI are the means and AFI and TCL are the big.

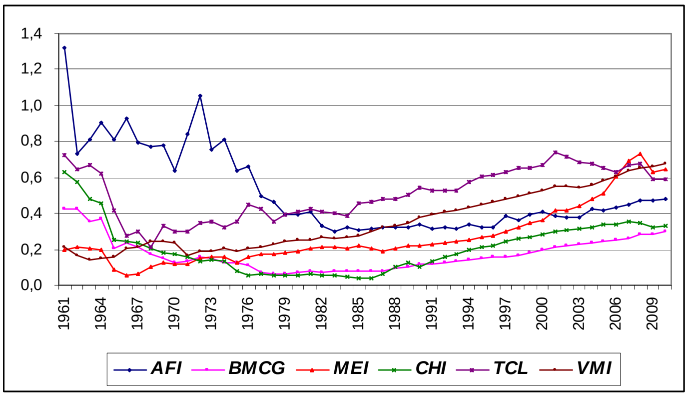

Figure 2 ***Evolution of the capital average productivity by sector***

Table ***4*** presents the results from the Tobit regression. It shows the statistical significance of coefficients related to:

- The level of the average productivity high and medium capital: both the sectors of average high productivity and those of average capital productivity are efficient;
- - The level of opening: the more business activity increases, the more the deviation cost increases;
- The labor force: the increased the number of workers especially the unskilled by sector causes an increase the deviation of total cost;

In addition, the level of intermediate consumption has not shown its importance on costs. In fact, a possible explanation for this is that the expenses are direct competence of the sectors.

The global picture from the regression analysis shows that the major sectors with high or average productivity, having commercial activities and not specifically oriented towards the promotion of activities beyond their respective compulsory services, are cost efficient. In other words, sectors generate costs to maintain a mix of infrastructure and manufactured products. In sectors with the characteristics mentioned above, the relationship between consumption expenditure and the costs incurred appears to be optimal.

Table 4 ***Explanation of inefficiency (Tobit regression)***

Variable	*coefficient*	*t-statistic*	*p-value*
Rev_high	-5.53	-10.48	0.000***
Rev_medium	-3.18	-7.63	0.000***
Log(com)	0.39	2.59	0.010***
Log(L)	0.55	2.38	0.018**

Log(Cons)	-0.30	-1.54	0.126
Constant	3.63	3.28	0.001***
Log Likelihood		-579.468	

***, ** Significance at 1% and 5%.

This work recognizes the essential role played by the new non-convex decomposition of cost efficiency frontier in determining the capacity utilization. Our analysis shows that, despite the general downward trend in the measurement of the capacity utilization in manufacturing over the years, it has shown ups and downs compatible with phases of expansions and contractions in the overall Tunisian economy.

CONCLUSION

This paper proposes a new way to break down the total cost frontier into three components (corresponding to short- and long-run cost notions): (a) short-run variable cost efficiency; (b) capacity utilisation of fixed inputs; and (c) scale efficiency. As suggested in the first section, the methodology is such that this decomposition should precede the traditional breakdown of costs into its technical and allocative components. Thus, these components have economic significance when dividing up short-run variable cost efficiency, but do not affect the long-run total cost efficiency because the factors that increase the excess in the total costs are more closely related to long-run decision variables. To our knowledge, the methodologies, the most widely used when analysing the cost frontier efficiency do not allowed this separation. Inevitably, this can introduce a bias in the obtained results. It seems that, when fixed inputs are present, the standard prescriptions from non-parametric models can actually be inapplicable.

To overcome these limitations, the flexible model proposed fits perfectly into the existing operative conditions. It allows for the quantification of the deviations observed on the total costs and establishes the chronological priorities of the required adjustments in both the long and the short run.

From an empirical point of view, the proposal was applied to a sample of the Tunisian industrial sector. This application illustrates a situation of a certain degree of cost inefficiency (the excess of costs inefficiency sectors globally reaches 19% of the total costs). Decomposing the global deviations helps us better understand the previous result: the short-run variable cost deviation is 0%; the overall inefficiency comes from the deviation of scale. Thus, the majority of the cost excess can only be addressed from the long-run perspective and which depends on the real possibilities to modify the structure of the sectors. From this perspective, to adjust the cost inefficiency observed, actions should influence the size of the sectors in order to orientate them towards their optimal scale.

The statistical exploration of the factors that could explain the results show that the results of this study can be justified by the multiple regression of the Tobit model. In fact, the Tobit regression coefficients show that large sectors, which have a high or an average productivity of capital, commercial activities, and not especially oriented towards the promotion of the industrial activities beyond their respective compulsory services, are profitable.

The political implications of the results presented here suggest the need for the separation between the short- and long-run cost inefficiencies. Short-run inefficiencies can be easily controlled simply by breaking the budget. In contrast, the long-run inefficiencies are more difficult to manage because they require a strategic point of view, the time and the capacity to change the structural situations.

To conclude, this study presents a diagnosis that focuses on the fundamental causes of inefficiency of the Tunisian industrial sector. However, the need for further studies to incorporate some uncontrollable factors, at this stage, is incontestable. The most important extensions are related to: (a) the introduction of specific prices for complete decomposition by introducing technical and allocative components, (b) control of the impact of environmental factors and the level of the production quality on the total costs (c) the temporal analysis of the cost changes, and (d) the inclusion of branches of the activities of the sectors with different financial regulations and industrial structures.

References

Balaguer-Coll, M. T., Prior, D. and Tortosa-Ausina, E., 2007, On the determinants of local government performance: a two-stage nonparametric approach, *European Economic Review*, forthcoming.

Banker, R. D. and Morey, R. C., 1986, Efficiency analysis for exogenously fixed inputs and outputs, *Operations Research*, vol. 34, pp. 513–21.

Briec, W., Kerstens, K. and Vanden Eeckaut, P., 2004, Non-convex technologies and cost functions: definitions, duality and nonparametric tests of convexity, *Journal of Economics*, vol. 81, pp. 155–92.

Deprins, D., Simar, L. and Tulkens, H., 1984, Measuring labor-efficiency in post offices, in M. Marchand, P. Pestieau and H. Tulkens (eds), *The Performance of Public Enterprises: Concepts and Measurement*, Amsterdam: North-Holland.

Färe, R. and Grosskopf, S., 2000, Theory and application of directional distance functions, *Journal of Productivity Analysis*, vol. 13, pp. 93–103.

Färe, R., Grosskopf, S., and Lee, H., 1990, A nonparametric approach to expenditure-constrained profit maximization, *American Journal of Agricultural Economics*, vol. 72, pp. 574–81.

Giménez, Victor M., 2004, Un modelo FDH para la medida de la eficiencia en costes de los departamentos universitarios, *Hacienda Pública Española / Revista de Economía Pública*, vol. 168, pp. 69–92.

Giménez, Victor M. and Diego Prior, 2007, Long- and Short-Term Cost Efficiency Frontier Evaluation: Evidence from Spanish Local Governments. *Fiscal Studies*, vol. 28, no. 1, pp. 121-139.

Hausman, W. and Neufeld, J., 1991, Property rights versus public spirit: ownership and efficiency of U.S. electric utilities prior to rate of return regulation, *Review of Economics and Statistics*, vol. 73, pp. 414–23.

Park, B. U., Simar, L. and Weiner, C., 2000, The FDH estimator for productivity efficiency scores, *Econometric Theory*, vol. 16, pp. 855–77.

Primont, D., 1993, Efficiency measures and input aggregation, in W. E. Diewert, K. Spremann and F. Stehling (eds), *Mathematical Modelling in Economics*, Berlin: Springer-Verlag.

Prior, D., 2003, Long- and short-run non-parametric cost frontier efficiency: an application to Spanis savings banks, *Journal of Banking and Finance*, vol. 27, pp. 655–71.

Simar, L. and Wilson, P. W., 2000, Statistical inference in nonparametric frontier models: the state of the art, *Journal of Productivity A nalysis*, vol. 13, pp. 49–78.

Tulkens, H., 1993, On FDH efficiency analysis: some methodological issues and applications to retail banking, courts, and urban transit, *Journal of Productivity Analysis*, vol. 4, pp. 183–210.

Vanden Eeckaut, P., Tulkens. H. and Jamar, M., 1993, Cost efficiency in Belgian municipalities, in H. Fried, C. A. K. Lovell and S. Schmidt (eds), *The Measurement of Productive Efficiency: Techniques and Application*, Oxford: Oxford University Press.