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An Empirical Analysis of Capacity Utilization and Total Factor Productivity to Inference on Technical Efficiency Level of Tunisian Manufacturing Industry

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Abstract: In this article, we tried to examine the various definitions stated in the literature about the performance and measurement of the capacity utilization rate, the total factor productivity and the technical efficiency. This study stresses two basic points. On the one hand, it gives an idea about the state of the Tunisian manufacturing industry of which it is essential to define the relevant guidance of such economic policy. On the other hand, it presents the stochastic methods, which are able to integrate the multifactor productivity in the cost model, and then the measurement of technical efficiency and the capacity utilization. Our results show that, despite the technological progress, there is a decline in productivity growth over the 1961/2014 period due to the growing inefficiency. The under-use of production capacity in the different sectors of the Tunisian manufacturing industry was considered a consequence of the excess capacity and the lack of efficiency attributed mainly to the lack of competition, which enables farms to operate below their frontier if they are protected on the market.

Keywords: Capacity Utilization, Total Factor Productivity, Substitution Elasticity, Technical Efficiency, Tunisian Manufacturing Sectors

1. Introduction

In March 2013, the Tunisian Center of Watch and Business Intelligence (TCWBI) stated that as far as the rhythm of the capacity utilization rate is concerned, 66.7% of the manufacturing firms showed operating levels lower than those of the installed capacity. According to the same report, only 4.8% declared operating levels above their capabilities. This relative weakness in the capacity utilization rate does not seem to affect the production level, at least for 65% of companies. Nevertheless, the question of capacity utilization (*CU*) still remains a challenge, mainly when considering the impact of the production capacity under-use could have on the investment decisions. From this point of view, understanding one's production capacity enables the organization to define its competitiveness limits and opportunities.

In fact, the current economic situation can only be explained by the real problems facing Tunisia today, influencing the productivity and competitiveness of firms. In this regard, it is recommended to diagnose, with the development of clear prospects, short-run problems that hinder growth, including problems of optimal resources allocation, financing and cash flow.

Tunisia has not managed to break the economic growth of 5% ceiling on the long term. In addition, since the revolution in 2011, the situation deteriorated and the rate of growth was close to zero in 2015. The issue of economic growth has become crucial for the future of the country.

Regarding the problem of the full use of the production factors, the production capacity (*PC*) measurement is one of the most significant issues affecting a nation's future growth. Indeed, this measure is necessary because an excessive capacity may lead to useless costs, and a deficient capacity results in market dissatisfaction. Reaching a good equilibrium of the whole production system is necessary for an optimum use of the capacity. In other terms, the projected equilibrium of cost-capacity management is the main objective of the firm.

When considering a productive combination, the economic performance is translated by the intersection of several variables and their corresponding relations. The understanding of the intersection between long-term economic growth and efficiency is one of the most important microeconomic theory studies. In fact, the impact of technical efficiency (*TE*) on growth was extensively discussed in the economic literature.

In this framework, some firms perform better than others do. This is due, in a first place, to the quality of their organization, which enables them to better manage the physical flows or the raw material processing. These firms are said to be technically efficient because they control better the production technical aspects and, consequently, manage to give the maximum of outputs using some limited resources level or the minimum of resources for a given level of production factors. Therefore, this first concept of efficiency involves only the issues of the physical quantities of resources and the techniques, which help, link them up. A second efficiency concept refers to the knowledge of the resource prices. Indeed, the best firms are also those, which know these prices by choosing the combinations of the least expensive factors and giving the combinations of the most beneficial outputs. Hence, these firms are said to be economically or allocatively efficient because they can cope better than others with the competition pressures, especially, with the prices. The company's overall efficiency is then the product of these two types of efficiency.

Despite the persisting methodological differences, a consensus around Solow's opportunity [34, 35] and Swan's [36] measurement of the total factor productivity growth (*TFP*) was reached. In our model, the complete growth rate of the real output is solved based on two elements: the first is based on the input growth rates and the second is a residual one identified with the changes of the production efficiency. The impact of the inputs is linked to both the movements of the aggregated production function and the multifactor residual productivity depending on the changes of this production function. Berndt and Fuss [6] showed that this structure is based on the assumption that all the inputs, including the quasi-fixed ones and the capital, can freely adjust because of their price changes.

A higher productivity growth rate is important as it implies a greater per capita wealth creation, generating more employment opportunities and especially high-quality jobs. An economic growth strategy involving significant accumulation of factors is appropriate when a country has a large stock of untapped human resources, as it is the case for Tunisia [38]. It is still important to state that the *TFP* growth rate is a good indicator of the overall efficiency of the economy - it measures the improvement of efficiency in the use of these production factors. On the other hand, a low *TFP* growth suggests the existence of obstacles that hamper the resources reallocation for more productive activities and hinder the ability to create wealth and jobs. The increase in *TFP* (that is to say, improving the efficiency in the use of production factors), can occur within a production activity or a given sector, or may result from the reallocation of resources across sectors [18, 27].

Having introduced and defined the utility of three following concepts (*CU*, *TFP* and *TE*), we have organized the remaining of this article as follows. The second part introduces their different modelling ways. The data, the results and the interpretations are dealt with in the third part. Finally, we end up with a conclusion in which the main findings are highlighted.

2. Theoretical Modelling

2.1. Primal Economic Measures of Capacity Utilization

According to Berndt and Morrison [5] and Helali and Kalai [15], the definitions of the production capacity and the capacity utilization are short-term concepts conditioned by the quasi-fixed input represented, generally, by the supply of the company capital *K*. A company is identified by its production function as follows:

$$Y = f\left(v; X; t\right) \tag{1}$$

where *Y* is the output level, *v* an (*n* x *1*) vector of the variable inputs, *K* a (*j* x *1*) vector of the quasi-fixed input level, and *t* a trend component representing the technological state. As it was underlined by McFadden [26], Diewert [10] and Lau [24], the optimization problem for the company is typically characterized by a maximization of the profit variable conditioned by the output price *p*, the prices of the variable inputs p_v, and the demand for the input *K*. An alternative structure used based on the recent developments of the duality theory considers the company optimization problem as a minimization of the variable cost. In this dual approach, and because of the production function regularity conditions, there is a dual variable cost function:

$$VC = C\left(p_j; Y, K; t\right) \tag{2}$$

where *VC* is the variable cost, p_j a vector of the variable input prices, *Y* the production level, *K* the stock of fixed capital, and *t* the technological state. Furthermore, we define the short-run total cost represented by:

$$TC_{SR} = VC + FC \tag{3}$$

where *FC* is the fixed cost equal to $FC = p_K.K$ with p_K is the capital user cost. Dividing equation (3) by the output *Y*, the short-run average total cost (ATC_{SR}) function is the following:

$$ATC_{SR} = AVC + AFC \tag{4}$$

where *AVC* is the average variable cost and *AFC* is the average fixed cost. According to Corrado and Mattey [9] and Diewert and Fox [11], the short-run measure of the production capacity is determined by the level that minimizes the short-run average total cost. If Y_m is the output that minimizes the ATC_{SR} curve, then, according to equation (4), it can be written as:

$$\frac{\partial ATC_{SR}}{\partial Y_m} = \left(\frac{1}{Y_m}\right)\left(\frac{\partial VC}{\partial Y_m}\right) - \frac{VC}{{Y_m}^2} - \frac{p_K.K}{{Y_m}^2} = 0 \quad (5)$$

This differentiation allows the generation of the Y_m value assuming that $Y_m = Y(K; p_j; p_K; t)$.

The alternative measure of the long-run production capacity suggested by Klein [22] and Friedman [13] corresponds to the curve tangency of the short-run average total cost, ATC_{SR}, and that of the long-run average total cost ATC_{LR}, noted Y_t. In the long run, all the factors are variable. A firm chooses to use a plan, which minimizes the short-run total cost for a given level of production. Based on equation (3), this implies:

$$\frac{\partial TC_{SR}}{\partial K^*} = \frac{\partial VC}{\partial K^*} + p_K = 0 \quad (6)$$

with $\partial VC / \partial K^* = R_K$ being the capital *Shadow Price* representing the reduction of the variable cost by getting an additional *K* unit. The resolution of equation (6) enables to pick up the value of the production capacity Y_t assuming that $Y_t = Y(K; p_j; p_K; t)$.

These two measures of the production capacity (Y_m and Y_t) were theoretically and empirically generalized by Morrison [29] to include non-constant returns to scale (NCRS). A formulation used based on the notion of the shadow cost function and suggested by Berndt and Fuss [6, 7] identifies the concept of production capacity as being the output, which corresponds to the stable state in which all the exogenous variables, including the fixed input stock, are assigned values.

The temporary balance is imposed by leveling the functions of the overall and shadow costs, or equivalently, by leveling the shadow value of the capital to the market price. More specifically, the shadow total cost function at NCRS can be schematized by:

$$TCf_{SR} = VC - R_K.K \quad (7)$$

where TCf_{SR} is the short-run shadow total cost function. With reference to Cassels [8] and Hickman's [17] works, production capacity is the minimum of the ATC_{SR} curve. In our case, the maximum output is defined by the minimum of the shadow average total cost function ($ATCf_{SR}$). By dividing equation (7) by the real production *Y*, we get the shadow average total cost function as follows:

$$ATCf_{SR} = AVC - (R_K.K/Y) \quad (8)$$

If Y_m is the output that minimizes the shadow average total cost function, then, according to equation (8), we get:

$$\frac{\partial ATCf_{SR}}{\partial Y_m} = \left(\frac{1}{Y_m}\right)\left(\frac{\partial VCV}{\partial Y_m}\right) - \frac{VC}{{Y_m}^2} - R_K.\frac{K}{{Y_m}^2} = 0 \quad (9)$$

By imposing the equilibrium condition, in terms of the equality of the fictitious cost function with that of the total cost, the *CU* measure can be equivalent to the tangency specification where the returns to scale are constant (CRS). The short- and long-run marginal total costs curves (MTC_{SR} and MTC_{LR}) have to meet at the value representing the tangency point of the ATC_{SR} and ATC_{LR} curves. By definition, to determine the MTC_{SR}, only the inputs variable can fit in the short term, hence we get:

$$MTC_{SR} = \frac{dTCf_{SR}}{dY}_{|K=\bar{K}} = \frac{\partial VC}{\partial Y} \quad (10)$$

The MTC_{LR} curve derivation is more complex. Since $TC_{SR} = VC + FC$, the MTC_{LR} curve can be specified as follows:

$$\frac{dTC_{LR}}{dY} = \frac{dVC(p_j; Y, K; t)}{dY} + p_K.\frac{dK}{dY} = \frac{\partial VC}{\partial Y} + \frac{\partial VC}{\partial K}.\frac{\partial K}{\partial Y} + p_K.\frac{dK}{dY} \quad (11)$$

By equalizing MTC_{SR} to MTC_{LR}, we will have $\left(\frac{\partial VC}{\partial K} + p_K\right)\frac{\partial K}{\partial Y} = 0$. The resolution of equations (10) and (11) enables to evaluate the Y_m and Y_t production capacities.

2.2. Dual Economic Measure of Capacity Utilization

Let us consider a company represented by Figure 1 where point *B* is not necessarily at a higher-level cost than point *A* due to the fact that the optimum production level is not represented by the minimum of the ATC_{SR} curve. This is important for the specification of the NCRS; however, its drawback is that the company has to acquire the lowest average costs to balance its production capacity. As a result, the dual measure, noted CU_D, has to differentiate between a cost decline caused by short-run NCRS, and the implicit cost excess at the production stable state. Hence, the point *E* does not change the capacity utilization rate of the existent capacity. More specifically, the total cost, which varies according to the change of the output from Y^* to Y', can be represented by:

$$\frac{dLnTC}{dLnY} = \frac{\partial TC}{\partial Y}.\frac{Y}{CT} + \frac{\partial TC}{\partial K}.\frac{dK}{dY}.\frac{Y}{CT} \quad (12)$$

In the case of NCRS, and in the presence of a homothetic function, the impact of scale of all the inputs is the same, $\frac{dK}{dY}\frac{Y}{K} = \frac{1}{RS_{LR}} = \eta \neq 1$ where ES_{LR} represents the long-run economy of scale.

We have, $\frac{dK}{dY} = \frac{K}{Y}\eta$ and then equation (12) becomes $\frac{dLnTC}{dLnY} = \eta = \varepsilon_{CY} + \varepsilon_{CK}\eta$ or even

$$\varepsilon_{CY} = (1 - \varepsilon_{CK})\eta \quad (13)$$

Hence, the returns to scale (RS_{SR}) observed in the short run are split into two parts; one represents the pure imbalance $(1 - \varepsilon_{CK})$ and the other the long run returns to scale (η), since $RS_{LR} = 1/\eta$.

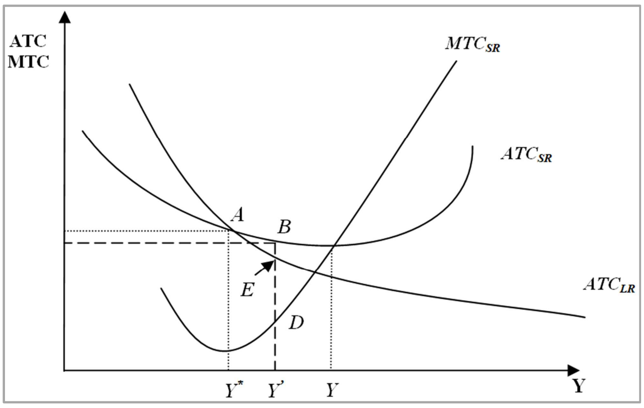

Figure 1. *Long- and short-run average and marginal total cost curves at NCRS.*

The information described by the CU_D measure is the impact of the cost in the under-utilization of the existing capacity and not on the long-run returns to scale (RS_{LR}). This is reflected in the change noticed in the cost relating to the effects of NCRS, $\eta(1-\varepsilon_{CK})/\eta = 1-\varepsilon_{CK}$. Therefore, the CU_D measure can be justified by:

$$CU_D = \frac{RS_{SR}}{RS_{LR}} = \frac{TCf(Y')}{TC(Y')} = \frac{\varepsilon_{CY}}{\varepsilon_{CY} + \eta\varepsilon_{CK}} = 1-(p_K + R_K).\frac{K}{CT} = 1-\varepsilon_{CK} \quad (14)$$

The return variation with the different inputs raises some problems since the scale factor can, in this case, differ from the fixed one compared to other inputs, but cannot eliminate it. Therefore, the capital constraint has an impact not only on the claim for the other inputs, witnessing a disequilibrium, but also on the facility to have a differentiation of the scale effect. This is to be noted under the following non-homothetic constraint:

$$\eta = \frac{dLnTC}{dLnY} = \frac{\partial LnTC}{\partial LnY} + \frac{\partial LnTC}{\partial LnK} = \varepsilon_{CY} + \eta_K.\varepsilon_{CK} \quad (15)$$

where $\frac{dLnK}{dLnY} = \eta_K = \frac{dK}{dY}\frac{Y}{K}$ and $\varepsilon_{CK} = \frac{\partial TC}{\partial K}.\frac{K}{CT} = (R_K + p_K)\frac{K}{CT}$. Since returns on capital differ from the total effect of scale, we will have:

$$\varepsilon_{CY} = \eta + \eta_K \varepsilon_{CK} = \eta\left[1-\left(\frac{\eta_K}{\eta}\right)\varepsilon_{CK}\right] \quad (16)$$

where $CU_D = \varepsilon_{CY}/\eta = 1-(\eta_K/\eta)\varepsilon_{CK}$. Due to the complete effect of the difference between the current and the optimum production, the fixed level *D*, must be reflected by the measure of CU_D, the measure of the shadow cost has to increase to be compatible with the marginal cost ratio (MC) which represents the costs assessed at the augmented fictitious value ($-R_K$), compared to the average cost (AC) as costs assessed in p_K. This means that:

$$R'_K = \left(\frac{\eta_K}{\eta}\right)R_K - \left(1-\left(\frac{\eta_K}{\eta}\right)\right)p_K \quad (17)$$

2.3. Translog Cost Function Specification

When Klein [22] proposed the CU short-term concept, he made some reserves about the practical difficulties in empirically estimating the ATC_{SR} curve parameters [23]. Apparently, for some reason, he proposed some CU alternative measures related to the cost economic theory. Referring to Morrison [30, 31], Helali et al. [16] and Kalai and Helali [21], the short-run Translog variable cost function at NCRS can be written as:

$$\begin{aligned} LnVC = {} & \alpha_0 + \alpha_t t + \frac{1}{2}t^2 + \sum_{i=L,E}\alpha_i Lnp_i + \beta_Y LnY + \beta_K LnK + \frac{1}{2}\sum_{i=L,E}\sum_{j=L,E}\delta_{ij}Lnp_i Lnp_j + \frac{1}{2}\gamma_{YY}(LnY)^2 \\ & + \frac{1}{2}\gamma_{KK}(LnK)^2 + \sum_{j=L,E}\rho_{Yi}LnYLnp_i + \sum_{j=L,E}\rho_{Ki}LnKLnp_i + \rho_{YK}LnYLnK + \rho_{tY}tLnY + \rho_{tK}tLnK + \sum_{i=L,E}\rho_{ti}tLnp_i \end{aligned} \quad (18)$$

Checking the homogeneity, in relation to the first-degree price, requires imposing the following constraints:

$$\alpha_L + \alpha_E = 1\,;\ \delta_{LL} + \delta_{LE} = 0\ ;\ \delta_{EE} + \delta_{LE} = 0\,;\ \rho_{YL} + \rho_{YE} = 0\,;\ \rho_{KL} + \rho_{KE} = 0\,;\ \rho_{tL} + \rho_{tE} = 0 \quad (19)$$

As far as the empirical involvement is concerned, and based on Shephard's lemma, it is useful to use additional equations that reflect the optimizing behavior. The equations of the optimal demand or cost minimization (the share of variable cost, S_i) are obtained by logarithmically differentiating the cost function variable in relation to the price logarithms of the variable inputs p_L and p_E considering *K*, *Y* and *t*. Actually, we have:

$$S_i = \frac{\partial LnVC}{\partial Lnp_i} = \frac{p_i X_i}{VC} = \alpha_i + \delta_{ii}Lnp_i + \delta_{ij}Lnp_j + \rho_{Yi}LnY + \rho_{Ki}LnK + \rho_{ti}t \quad \forall i \neq j = L,E \quad (20)$$

The above variable input equations are exactly similar to those obtained when using the traditional Translog cost function under the assumption that all the inputs (including the capital) are instantly adjusted, except that the estimated "share equations" are based on the quantitative level of the capital *LnK* instead of the capital price Lnp_K. However, the only significant difference is that, with a variable cost function, the cost of the quasi-fixed input can be calculated and compared with its user cost. Therefore, if a logarithmic differentiation is applied to the Translog variable cost function in relation to the capital change, the result will be a logarithmic version of the shadow value. Let S_K be the shadow capital share of the cost, then, we have:

$$S_K = \frac{\partial LnVC}{\partial LnK} = \frac{R_K K}{VC} = \beta_K + \rho_{KL} Lnp_L + \rho_{KE} Lnp_E + \rho_{YK} LnY + \gamma_{KK} LnK + \rho_{tK} t \quad (21)$$

It should be noted that the R_K value is endogenous and reflects the best possible condition to the achievement of the firm's objective given the constraints it faces. In this context, it is worth noting that if the firm's price is specified in the marginal production cost, then the logarithmic differentiation of the cost function, due to the change of Y and of the price, gives:

$$S_Y = \frac{\partial LnVC}{\partial LnY} = \frac{p.Y}{VC} = \beta_Y + \rho_{YL} Lnp_L + \rho_{YE} Lnp_E + \gamma_{YY} LnY + \rho_{YK} LnK + \rho_{tY} t \quad (22)$$

By imposing various restrictions on both cost function and share equations, we get the equation system (23).

$$\begin{cases} Ln\left(\frac{VC}{p_L}\right) = \alpha_0 + \alpha_t t + \frac{1}{2}\gamma_{tt} t^2 + \alpha_E Ln\left(\frac{p_E}{p_L}\right) + \beta_Y LnY + \beta_K LnK + \frac{1}{2}\delta_{EE} Ln\left(\frac{p_E}{p_L}\right)^2 + \frac{1}{2}\gamma_{KK}(LnK)^2 \\ +\frac{1}{2}\gamma_{YY}(LnY)^2 + \rho_{YK} LnYLnK + \rho_{YE} LnY\,Ln\left(\frac{p_E}{p_L}\right) + \rho_{KE} LnK\,Ln\left(\frac{p_E}{p_L}\right) + \rho_{tY} tLnY + \rho_{tK} tLnK + \rho_{tE} tLn\left(\frac{p_E}{p_L}\right) \\ S_L = \alpha_L + \delta_{LE} Ln\left(\frac{p_E}{p_L}\right) + \rho_{YL} LnY + \rho_{KL} LnK + \rho_{tL} t \\ S_E = \alpha_E + \delta_{EE} Ln\left(\frac{p_E}{p_L}\right) + \rho_{YE} LnY + \rho_{KE} LnK + \rho_{tE} t \\ S_K = \beta_K + \rho_{KE} Ln\left(\frac{p_E}{p_L}\right) + \rho_{YK} LnY + \gamma_{KK} LnK + \rho_{tK} t \\ S_Y = \beta_Y + \rho_{YE} Ln\left(\frac{p_E}{p_L}\right) + \gamma_{YY} LnY + \rho_{YK} LnK + \rho_{tY} t \end{cases} \quad (23)$$

By imposing various restrictions on both cost function and share equations, we get the equation system (23). To solve the singularity problem, it is necessary to eliminate equation S_L since $S_L + S_E = 1$. Using Zellner's [39] constraint iterative SURE method, the system is then estimated.

If Y_m is the output which minimizes the shadow average total cost function, then, according to equation (8), we will have:

$$\frac{VC}{Y_m^{\,2}}\left(\beta_Y + \rho_{YE} Ln\left(\frac{p_E}{p_L}\right) + \gamma_{YY} LnY + \rho_{YK} LnK + \rho_{tY} t - 1\right) + R_K \frac{K}{Y_m} = 0 \quad (24)$$

Regarding the second primal economic measure Y_t, which implies that the production capacity is the tangency point of the ATC_{SR} and ATC_{LR} curves, then we will have:

$$\left(\beta_K + \rho_{KE} Ln\left(\frac{p_E}{p_L}\right) + \rho_{YK} LnY_t + \gamma_{KK} LnK + \rho_{tK} t\right)\frac{VC}{K} = -p_K \quad (25)$$

Relying on equations (24) and (25) the estimation of Y_m and Y_t is not possible using an analytical method because these equations depend on both Y and $Ln\ Y$. Therefore, it is necessary to apply a numerical iterative procedure. Once the economic measures Y_m and Y_t are estimated, both *CU*s are calculated at NCRS as follows: $CU_m = Y/Y_m$ and $CU_t = Y/Y_t$.

When estimating the CU_D, we should refer to the previous theoretical developments in which we find:

$$CU_D = \frac{S_Y\,VC}{\frac{S_Y\,VC}{Y} + \frac{dLnK}{dLnY}\cdot\frac{(p_K + R_K)K}{CTV + p_K K}} \quad (26)$$

2.4. Short- and Long-Run Elasticity Developments

The elasticity concept plays a major role in econometric models due to its synthesizing property. Methodologically, elasticity might appear, as a by-product with the same title, only with the equation estimated coefficients. The logarithmic form of the Translog cost function makes imposing constraints and calculating elasticity easier in order to explain, at equilibrium, the impacts of the production factors prices on the demand costs, the output amount and the capital.

In the short-run, it should be noted that the short-run average total cost curve position depends on the levels of the prices factor and the capital amount. It is important to calculate the production price elasticity noted as ε_{Yi}^{SR}. At the NCRS, the production capacity is evaluated with reference to the shadow total cost function. A balance is obtained since $\frac{\partial TCf}{\partial K^*} = \frac{\partial VC}{\partial K^*} + p_K = 0$.

Let $\frac{\partial TCf}{\partial Y^*} = -\frac{R_K K}{Y^{*2}} - \frac{p_K K}{Y^{*2}} = 0 \equiv f_Y$ where f_Y is the marginal variable cost, the total f_Y differential can be written as $df_Y = \frac{\partial f_Y}{\partial Y^*} dY^* + \sum_{i=L,E} \frac{\partial f_Y}{\partial p_i} dp_i + \frac{\partial f_Y}{\partial K} dK + \frac{\partial f_Y}{\partial t} dt = 0$. Regarding our short-run function, the production capacity elasticity, due to the change of the input prices, is defined by:

$$\varepsilon_{Yi}^{SR} = \frac{\rho_{Ki} + S_K S_i}{\rho_{YK} + S_K S_Y} \tag{27}$$

As for the substitution elasticity between the production variable factors noted Allen's Substitution Elasticity (AES), σ_{ij} and σ_{ii} represent the cross-price or the demand elasticity of asset *i* due to the change of the *j* asset price, and the direct price elasticity, respectively. In fact, $\sigma_{ij} = \frac{\partial LnX_i}{\partial Lnp_j} = \frac{\partial X_i}{\partial p_j}\frac{p_j}{X_i}$ and $\sigma_{ii} = \frac{\partial LnX_i}{\partial Lnp_i} = \frac{\partial X_i}{\partial p_i}\frac{p_i}{X_i}$, therefore:

$$\sigma_{ij}^{SR} = \frac{\delta_{ij} + S_i S_j}{S_i} \text{ and } \sigma_{ii}^{SR} = \frac{\delta_{ii} + S_i^2 - S_i}{S_i} \tag{28}$$

In the long-run, considering the AES standard case, we will have $R_K = S_K.VC/K$. Since *K* varies where p_K is adjusted to R_K, $\partial K/\partial p_K$ can be calculated. Therefore, the impact of the capital price change in relation to the capital stock is denoted by:

$$\varepsilon_{KK}^{LR} = \frac{\partial LnK}{\partial Lnp_K} = -\frac{S_K}{\gamma_{KK} + S_K^2 - S_K}\frac{p_K}{R_K} \tag{29}$$

To calculate the long-run cross elasticities of the impact of the input price variation on the capital noted ε_{Ki}^{LR}, we can then write $\varepsilon_{Yi}^{SR} = -\frac{\partial LnK}{\partial Lnp_i}\Big|_{Y;p_j;p_K} = \varepsilon_{Ki}^{LR}$; $i = L, E$. In fact, in the long run, we will have $\frac{S_K.VC}{K} + p_K = 0 \equiv f_K$ where f_K is the capital marginal cost. The total differential of f_K can be written as follows:

$$df_K = \frac{\partial f_K}{\partial Y^*}dY^* + \sum_{i=L,E}\frac{\partial f_K}{\partial p_i}dp_i + \frac{\partial f_K}{\partial K}dK + \frac{\partial f_K}{\partial t}dt = 0 \tag{30}$$

However, for the short-run Translog cost function at NCRS, and given the change of the input prices, the capital elasticity is defined by:

$$\varepsilon_{Ki}^{LR} = -\frac{\partial LnK}{\partial Lnp_i} = \frac{\rho_{Ki} + S_K S_i}{\gamma_{KK} + S_K^{\;2} - S_K} = \varepsilon_{Yi}^{SR}\ ;\ i = L, E \tag{31}$$

On the other hand, the long-run cross-price elasticity of the variation level of factor *i,* given the capital price noted ε_{iK}^{LR}, is defined by:

$$\varepsilon_{iK}^{LR} = \frac{\partial LnX_i}{\partial Lnp_K} = -\left(\frac{\rho_{Ki} + S_K S}{\gamma_{KK} + S_K^{\;2} - S_K}\right)\frac{S_K p_K}{S_i R_K}\ ;\ i = L, E \tag{32}$$

Most industrial sectors can be specified by the situation where the economies of scale ($\varepsilon_{Yt}^{LR} < 1$) exist and the *CU* is relatively weak, such as $\varepsilon_{CY} < 1$ and, as a result, there will be a weak measure of the *TFP*. Due to the fixed nature of the socio-economic infrastructure, the long-term economies of scale ε_{CY}^{LR} are measured throughout the AC_{LR} curve. Graphically, this relationship implies that if the *CU* < 1, then, the slope of the AC_{SR} curve is steeper than that of the AC_{LR}. Hence $\varepsilon_{CY}^{LR} > \varepsilon_{CY}^{SR}$, where the short-term economies of scale are larger than the long-term ones.

2.5. Total Factor Productivity Formulation

Since Solow's [35] work appeared, several studies have attempted to adjust the growth measurement of the total factor productivity to the capacity utilization; however, these adjustments remained pro-cyclical. This is the result of using ad hoc proxies of the capacity utilization that require adequate theoretical frameworks [37].

Most of the used models to analyze productivity are based on the assumption of full utilization or a long-term balance as well as static expectations in every way for all the inputs. More specifically, these models are mainly based on the assumption that firms generally use efficient technological and economic combinations. Therefore, productivity growth can be represented by $\varepsilon_{ft} = \partial LnY/\partial t$, where *Y* is the output defined by the production function $Y = f(X)$, and *t* is the technological condition, or by $\varepsilon_{Ct} = -\partial LnC/\partial t$, where *C* is the short run total cost ($TC_{SR} = \sum_{j=1}^{J} p_j v_j + \sum_{m=1}^{M} p_m X_m$) (see [4, 14]).

Due to the technical progress, the total cost variation represented by $dLnC/dt$ is characterized by the total response of the variable and fixed inputs to the long-term balance levels.

$$\frac{\dot{C}}{C} = \frac{dLnC}{dt} = \frac{1}{C}\left[\frac{dC}{dt}\Big|_{X_m = \overline{X_m}} + \sum_m \frac{\partial C}{\partial X_m}\frac{dX_m}{dt}\right] \tag{33}$$

This long-term cost elasticity is similar to the long-term price and the output elasticities. In fact, the long-run adjustment is a geometric series of adjustments on the side of the stock of the quasi-fixed inputs *X**, which are supposed to define the difference between *X* and *X** in proportion to λ for each period. This decomposition gets the atmosphere of the difference between the productivity short and long-term impacts. However, it is not very useful to interpret the imbalance concept or the *CU*. To make the interpretations easier, assuming that there are constant returns to scale, the following expression is developed (33):

$$\frac{\dot{C}}{C} = -\varepsilon_{Ct} + \left(1 - \sum_m \varepsilon_{Cm}\right)\frac{\dot{Y}}{Y} + \sum_j \frac{v_j p_j}{C}\frac{\dot{p}_j}{p_j} + \sum_m \frac{p_m X_m}{C}\frac{\dot{p}_m}{p_m} + \sum_m \frac{(p_m + R_m)X_m}{C}\frac{\dot{X}_m}{X_m} \tag{34}$$

Actually, according to Lau [25] and Morrison [30], with only one quasi-fixed input and without any dynamic behavior $\frac{\partial LnC}{\partial LnY}=\frac{\partial C}{dY}\frac{Y}{C}+\frac{\partial C}{dK}\frac{K}{C}=1$ since with the CRS, $\partial LnK/\partial LnY=1$, therefore, $\varepsilon_{CY}+\varepsilon_{CK}=1$. The fall of the cost is supposed to be positive $\varepsilon_{Ct}=-\partial LnC/\partial t$, hence, productivity growth is represented by a high number of inputs instead of a lower one. Moreover, it should be noted that dX_m/dt represents the change effect of *t* on the long-term capital stock as well as on investment. Following Ohta [32], in the long term $\dot{C}/C$ may be represented as:

$$\frac{\dot{C}}{C}=\sum_j\frac{v_jp_j}{C}\frac{\dot{p}_j}{p_j}+\sum_m\frac{p_mX_m}{C}\frac{\dot{p}_m}{p_m}+\sum_m\frac{p_mX_m}{C}\frac{\dot{X}_m}{X_m} \quad (35)$$

By making both of the above expressions $\dot{C}/C$ equal, we get:

$$\varepsilon_{Ct}=\left(1-\sum_m\varepsilon_{Cm}\right)\frac{\dot{Y}}{Y}+\sum_j\frac{v_jp_j}{C}\frac{\dot{p}_j}{p_j}+\sum_m\frac{R_mX_m}{C}\frac{\dot{X}_m}{X_m} \quad (36)$$

This expression is actually the residual conventional productivity calculated as the difference between the output change and the weighted sum of the input parts of change or as the cost changes minus the weighted sum of the current parts of the various inputs. It should be noted that equation (36) is valid in the long-run equilibrium and with the existence of the CRS. The importance of ε_{Ct} representation in (36), is that it can be made clearer by dividing it by $1-\sum_m\varepsilon_{Cm}$. Hence, we get:

$$\frac{\varepsilon_{Ct}}{1-\sum_m\varepsilon_{Cm}}=\varepsilon_{Ct}^{'}=\frac{\dot{Y}}{Y}=\frac{1}{1-\sum_m\varepsilon_{Cm}}\left[\sum_j\frac{v_jp_j}{C}\frac{\dot{p}_j}{p_j}+\sum_m\frac{R_mX_m}{C}\frac{\dot{X}_m}{X_m}\right] \quad (37)$$

The interpretation of the above expression requires more steps. Therefore, it should be noted that:

$$1-\sum_m\varepsilon_{Cm}=\frac{CT-\sum_m(p_m+R_m)X_m}{CT}=\frac{CTV-\sum_m R_mX_m}{CT}=\frac{C^*}{C}=\frac{\text{Shadow Costs}}{\text{Total Costs}} \quad (38)$$

The previous expression of the shadow cost is less different from the measure defined by Berndt and Fuss [6] as $TCf_{SR}=\sum_{j=1}^{J}p_jv_j-\sum_{m=1}^{M}R_mX_m$, where the contributions of the quasi-fixed inputs are weighted by their fictitious values instead of their real values. In fact, the expression of Berndt and Fuss [6] is based on the static optimization in which the contribution of the investment to the cost is not explicitly defined. With the dynamic optimization, the shadow costs are the net adjustment costs due to the fact that the capital marginal costs are known. By inserting (38) in (37), we get:

$$\varepsilon_{Ct}^{'}=\frac{\dot{Y}}{Y}-\left[\sum_j\frac{v_jp_j}{C}\frac{\dot{p}_j}{p_j}+\sum_m\frac{R_mX_m}{C}\frac{\dot{X}_m}{X_m}\right] \quad (39)$$

In (39), the expression $\varepsilon_{Ct}^{'}$ of the overall production factors with a $CU\neq1$, is similar to that of Berndt and Fuss [7]. In fact, these authors adjust the observed productivity ε_{Ct} taking into account the above disequilibrium. The development of the technical progress representation requires a demonstration of the equivalence of $\varepsilon_{Ct}^{'}$ with the measurement of $\varepsilon_{ft}^{'}$. Actually, it should be noted that, with fixed inputs, the arguments of the production function should be divided into variable and fixed inputs, thus, $Y=f(v_j;X_m;t)$. As a result, $\frac{dLnY}{dt}=\frac{\dot{Y}}{Y}+\sum_j\frac{v_jf_j}{f}\frac{\dot{v}_j}{v_j}+\sum_m\frac{f_mX_m}{f}\frac{\dot{X}_m}{X_m}+\varepsilon_{ft}$ where

$$\varepsilon_{ft}=\frac{\dot{Y}}{Y}+\sum_j\frac{v_j\mu f_j}{\mu Y}\frac{\dot{v}_j}{v_j}-\sum_m\frac{\mu f_mX_m}{\mu Y}\frac{\dot{X}_m}{X_m} \quad (40)$$

The assessment of (40) at the short-term values results in:

$$\varepsilon_{ft}^{'}=\frac{\dot{Y}}{Y}-\frac{1}{\varepsilon_{CY}}\left[\sum_j\frac{v_jp_j}{C}\frac{\dot{p}_j}{p_j}-\sum_m\frac{R_mX_m}{C}\frac{\dot{X}_m}{X_m}\right]=\frac{1}{1-\sum_m\varepsilon_{Cm}}\left[\sum_j\frac{v_jp_j}{C}\frac{\dot{p}_j}{p_j}-\sum_m\frac{R_mX_m}{C}\frac{\dot{X}_m}{X_m}\right]=\varepsilon_{Ct}^{'} \quad (41)$$

This last expression is directly analogous to $\varepsilon_{Ct}^{'}$ given by (39). It is possible, however, to introduce the true impact of the technological progress $\varepsilon_{Ct}^{'}$ as the product of two parts, hence, the observed production effect and that of the short-term strength or of the imbalance are:

$$\varepsilon_{ft}^{'}=\frac{\varepsilon_{ft}}{1-\sum_m\varepsilon_{Cm}} \text{ and } \varepsilon_{Ct}^{'}=\frac{\varepsilon_{Ct}}{1-\sum_m\varepsilon_{Cm}} \quad (42)$$

where, in the long-run, $\varepsilon_{Cm}=0$. Therefore, the $CU=1$ and $\varepsilon_{ft}^{'}=\varepsilon_{ft}=\varepsilon_{Ct}^{'}=\varepsilon_{Ct}$.

2.6. Technical Efficiency and Moment's Method

The evaluation of the economic efficiency can be decomposed into technical and allocative efficiency. In this sub-section, the focus will be on the technical efficiency; in other words, on the ability to produce as much as possible from fixed inputs amounts. Farrell [12] was the first to design the efficiency of a firm as the product of two components: technical efficiency, which reflects the ability of a firm to get the maximum output from a quantity of data inputs, and allocative efficiency, which reflects the ability of the firm to use its inputs in optimal proportions with their respective prices. A random error term *v* is added in equation (1). Therefore, we get a composed error model:

$$y = f(x,\beta) + (v - u) \tag{43}$$

with $u \geq 0$ and $-\infty \leq v \leq +\infty$. Hence, *v* is the difference caused by the uncertainties that affect production and which are not directly under the control of the manager. Furthermore, *v* and *u* are independent from each other and from *x* as well. Therefore, the relationship (43) can be reconfigured as follows:

$$y_i = \beta_0' + \sum \beta_j x_{ij} + \varepsilon_i' \tag{44}$$

with $\beta_0' = (\beta_0 - \mu)$ and $\varepsilon_i' = v_i - (u_i - E(u_i)) = v_i - (u_i - \mu) = \varepsilon_i + \mu$.

To assess the technical efficiency based on (44), a particular distribution should be specified for each error term. First, μ can be estimated using the method of moments and then β_0 [3]. Actually, using the residual vector $\hat{\varepsilon}'$ of (44), one can get an estimation of the moments of order two ($\hat{\mu}^2$) and three ($\hat{\mu}^3$) and therefore of $\hat{\sigma}_u^2$ and $\hat{\sigma}_v^2$. The variances $\hat{\sigma}_u^2$ and $\hat{\sigma}_v^2$ are estimated in a convergent way by:

$$\hat{\sigma}_u^2 = \left[\hat{\mu}_3 \sqrt{\frac{2}{\pi}}\left(\frac{\pi}{\pi - 4}\right)\right]^{2/3} \text{ and } \hat{\sigma}_v^2 = \hat{\mu}_2 - \left(\frac{\pi - 2}{\pi}\right)\hat{\sigma}_u^2 \tag{45}$$

The estimation of the central moments is given by the following equations:

$$\mu_2 = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(\varepsilon_{it} - \bar{\varepsilon})^2 \text{ and } \mu_3 = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(\varepsilon_{it} - \bar{\varepsilon})^3 \tag{46}$$

corresponding to Schmidt and Lovell's [33] moment equation of as follows:

$$\mu_2 = \frac{\pi - 2}{\pi}\sigma_u^2 + \sigma_v^2 \text{ and } \mu_3 = \sqrt{\frac{2}{\pi}}\left(\frac{4}{\pi} - 1\right)\sigma_u^3 \tag{47}$$

According to Jondrow et al. [19], cost inefficiencies are estimated through the average of the conditional distribution of u_{it} if ε_{it} is known, using the following expression:

$$E(u_{it}|\varepsilon_{it}) = \left(\frac{\sigma_u \sigma_v}{\sigma}\right)\left[\left(\varphi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right) \Big/ \Phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)\right) + \frac{\varepsilon_{it}\lambda}{\sigma}\right] \tag{48}$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u/\sigma_v$, and $\varphi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)$ and $\Phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)$ are the probability density and cumulative distribution functions of the standard normal distribution.

3. Empirical Analysis

3.1. Sample, Data and Variables

The data used in this study cover six sectors of the Tunisian manufacturing industry (TMI) observed over the 1961-2014 period. The individual industries included in the data set are: Agriculture and Food Industry (AFI), Building Materials, Ceramics and Glass (BMCG), Mechanical and Electrical Industries (MEI), Chemical industries (CHI), Textiles, Clothing and Leather (TCL), Various Manufacturing Industries (VMI). The used data set covers the Tunisian manufacturing industry with 324 observations. The number of periods (T = 54) exceeds that of sectors (N = 6). The data are collected from the 2016 Database of the Tunisian Institute of Competitiveness and Quantitative Studies (TICQS). These data contain production (*Y*), labor (*L*), capital stock at the beginning of each period (*K*), energy costs (*EC*), average annual salary (p_L), payroll (*PR*), capital user cost (p_K) and energy price (p_E).

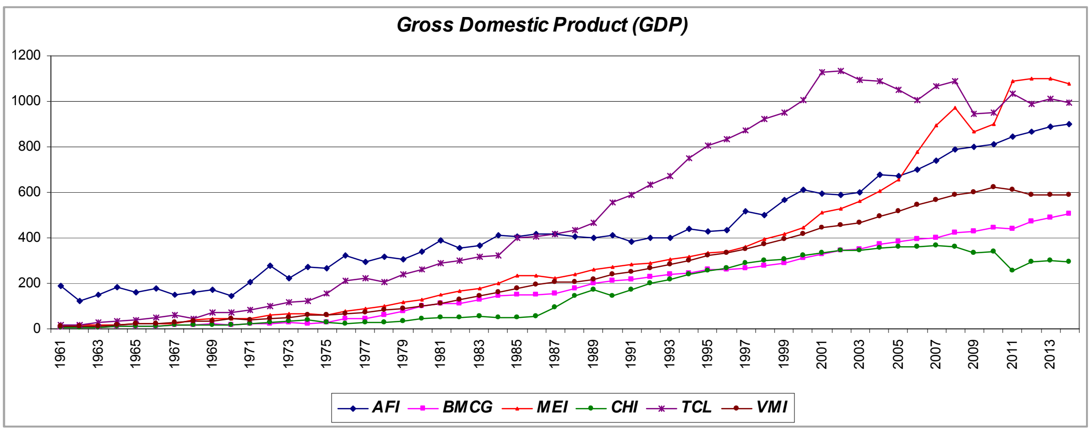

Figure 2. *Production evolution of the manufacturing industry by sector.*

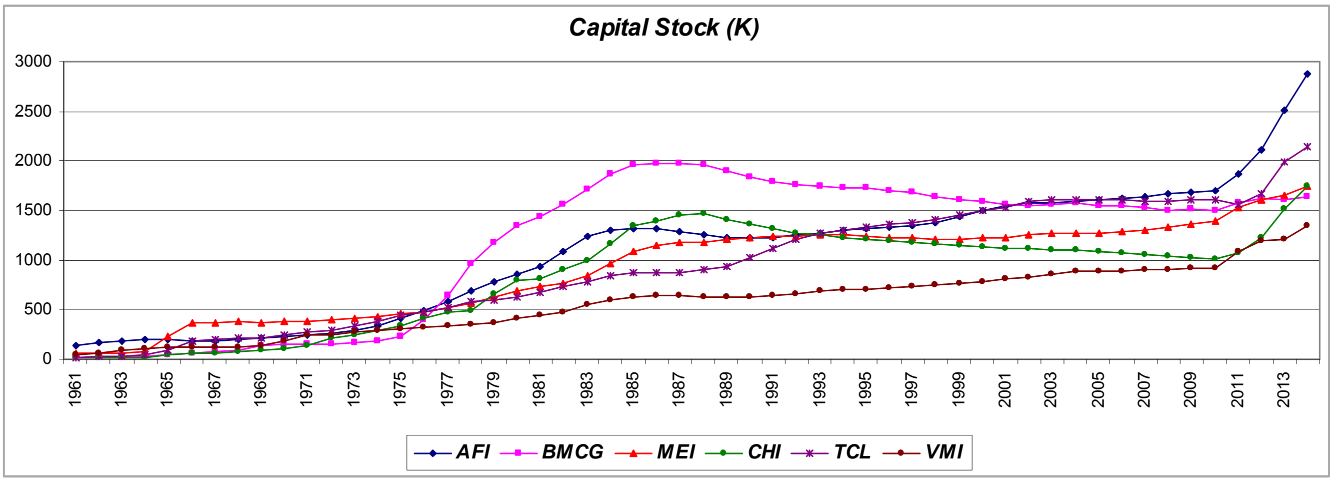

Figure 3. *Capital stock evolution of the manufacturing industry by sector.*

Figures 2 and 3 show the production and capital development in the different manufacturing industrial sectors. It is clear that there is an upward trend in the series with some breaking phases. This statement is proved by the descriptive analysis of Table 1.

Table 1. *Variables descriptive analysis.*

Sectors	Designations	*GDP (MTD)*	*p_Y (Index)*	*K (MTD)*	*p_K (Index)*	*L (10^3)*	*PR (MTD)*	*p_L (Index)*	*EC (MTD)*	*p_E (Index)*	*E (Units)*
AFI	Minimum	120.7	0.1	142.0	0.1	3.3	2.1	0.2	18.0	0.1	34.7
	Maximum	810.6	2.2	1700.4	2.8	59.9	749.4	3.4	152.0	2.6	184.0
	Average	401.2	0.8	972.9	0.9	29.2	175.7	1.1	57.8	0.9	90.5
	S-D	190.8	0.7	556.1	0.8	19.7	209.4	0.9	35.4	0.7	42.2
	OGR %	330.8	2201.4	1097.2	3692.9	1686.7	35585.7	1897.3	744.9	2533.4	-67.9
	AAGR %	3.0	6.6	5.2	7.7	6.1	12.7	6.3	4.5	6.9	-2.3
BMCG	Minimum	8.2	0.2	19.4	0.1	9.4	4.6	0.2	27.4	0.2	83.9
	Maximum	444.9	2.2	1973.5	3.0	35.4	418.5	4.0	299.7	2.2	162.7
	Average	171.7	0.9	1132.6	0.9	22.5	101.8	1.1	117.2	0.9	126.9
	S-D	142.2	0.6	738.5	0.9	9.3	112.0	1.0	77.3	0.6	15.4
	OGR %	5296.4	928.0	7673.8	3752.6	252.5	8997.8	2480.8	993.8	963.3	2.9
	AAGR %	8.5	4.9	9.3	7.7	2.6	9.6	6.9	5.0	4.9	0.1
MEI	Minimum	12.4	0.1	63.7	0.1	2.3	1.1	0.1	17.1	0.1	39.3
	Maximum	971.5	2.4	1392.6	3.0	96.0	759.9	2.2	202.8	3.1	125.8
	Average	279.3	0.9	858.4	0.9	32.2	173.5	0.9	66.9	1.0	81.2
	S-D	265.6	0.7	438.4	0.9	27.9	210.4	0.6	45.0	0.8	21.7
	OGR %	7155.2	1856.4	2086.0	4141.6	3921.3	68981.8	1617.9	1083.0	2147.5	-47.4
	AAGR %	9.1	6.3	6.5	7.9	7.8	14.3	6.0	5.2	6.6	-1.3
CHI	Minimum	6.7	0.2	10.7	0.1	4.1	1.8	0.1	75.3	0.2	79.4
	Maximum	368.5	3.1	1462.9	3.0	28.1	313.5	2.8	323.2	3.3	398.1
	Average	147.5	1.1	794.4	0.9	13.5	79.7	0.9	175.9	1.0	224.7
	S-D	137.8	0.7	503.5	0.9	6.8	86.4	0.8	79.9	0.7	70.5
	OGR %	4915.5	1295.8	9406.0	4148.4	482.6	17316.7	2889.6	318.5	1667.2	-76.3
	AAGR %	8.3	5.5	9.7	8.0	3.7	11.1	7.2	3.0	6.0	-2.9
TCL	Minimum	15.3	0.1	21.2	0.1	29.3	10.5	0.1	4.9	0.1	13.6
	Maximum	1134.4	2.2	1612.7	2.7	234.7	1838.7	3.2	85.3	4.8	67.8
	Average	492.3	0.9	872.0	0.9	107.0	411.6	0.9	28.4	1.1	35.3
	S-D	394.1	0.7	555.2	0.8	75.5	533.0	0.9	23.2	1.1	13.5
	OGR %	6102.6	2541.3	7518.9	3103.4	409.8	17411.4	3334.9	1654.5	6542.3	-73.6
	AAGR %	8.8	6.9	9.2	7.3	3.4	11.1	7.5	6.0	8.9	-2.7
VMI	Minimum	9.1	0.2	42.4	0.1	4.8	1.5	0.2	3.6	0.2	15.2
	Maximum	620.1	1.8	921.4	2.7	64.0	419.1	3.2	79.8	1.8	44.5
	Average	225.2	0.9	521.1	0.9	30.8	99.3	1.0	26.3	0.9	26.6
	S-D	192.0	0.5	283.0	0.8	21.2	118.8	0.9	21.3	0.5	9.3
	OGR %	6751.3	917.0	2072.6	3298.5	1239.3	27840.0	1986.2	2104.6	652.6	192.9
	AAGR %	9.0	4.8	6.5	7.5	5.4	12.2	6.4	6.5	4.2	2.2
TMI	Minimum	6.74	0.08	10.70	0.07	2.30	1.10	0.09	3.62	0.07	13.61
	Maximum	1134.40	3.11	1973.49	3.02	234.74	1838.70	4.04	323.15	4.76	398.06
	Average	286.22	0.92	858.57	0.92	39.23	173.59	0.99	78.73	0.94	97.53
	S-D	266.10	0.66	557.89	0.85	46.72	281.65	0.85	74.38	0.77	75.24

Sectors	Designations	*GDP (MTD)*	*p_Y (Index)*	*K (MTD)*	*p_K (Index)*	*L (10^3)*	*PR (MTD)*	*p_L (Index)*	*EC (MTD)*	*p_E (Index)*	*E (Units)*
	OGR %	229.6	1800.3	548.7	3599.1	1851.5	19857.1	1752.6	343.6	1735.3	-75.8
	AAGR %	0.4	1.0	0.6	1.2	1.0	1.8	1.0	0.5	1.0	-0.5
	Skewness	1.24	0.53	0.04	0.68	2.66	3.21	1.08	1.43	1.90	1.37
	Kurtosis	4.14	2.42	1.71	2.18	10.18	15.52	3.65	4.37	8.62	5.01
	Jarque-Bera	93.55	18.55	20.78	31.79	996.72	2471.85	63.40	126.43	575.73	143.83
	Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: OGR: the overall growth rate; AAGR: the average annual growth rate; MTD: Million Tunisian Dinars; S-D: Standard Deviation. Tunisian manufacturing industry (TMI), Agriculture and Food Industry (AFI), Building Materials, Ceramics and Glass (BMCG), Mechanical and Electrical Industries (MEI), Chemical industries (CHI), Textiles, Clothing and Leather (TCL), Various Manufacturing Industries (VMI).

Moreover, two different phases are generally observed. The first refers to low growth (1961-1994), mainly in the EMI and TCL sectors, and the second (1995-2014) to a strong growth in the upgrading period. Furthermore, a decline of the capital stocks occurred in the mid-90s in all the sectors, with the exception of the strong growth of the textile sector.

Empirically speaking, the equation of the average variable cost (*AVC*) and the demand equations, which are subject to the homogeneity and concavity restrictions, are short-term assessable equations. Assuming that the general form of the cost function is $y_{it} = \alpha_{it} + \beta' X_{it} + \varepsilon_{it}$, therefore, the error term can be specified as $\varepsilon_{it} = \nu_i + u_{it}$. The Panel error is then the sum of the behavioral errors u_{it} and of an individual specific effect ν_i.

A constrained iterative seemingly unrelated regression of Zellner [39] is applied to the equation system made up of the variable cost function and the corresponding demand equations for the purpose of improving the efficiency of the estimated parameters.

3.2. Capacity Utilization and Technical Efficiency Estimations

The assessment of the final iterative SURE model, after correcting the serial correlation and the heteroskedasticity adjustment, is summarized in Table 2. From this table, it can be deduced that the Translog variable cost function at the NCRS shows the economic evidence regarding the production factors signs and, in particular, the quasi-fixed capital ones. In fact, the convexity in relation to *K* and the concavity in relation to the prices of the variable inputs are tested. The estimated coefficients have expected signs, mainly the $\gamma_{KK} > 0$. The energy factor is positively correlated with the capital, which justifies the complementary effect between these two factors. All the trend effects are significant at least at 5%, but with different amplitudes excepting that of the capital.

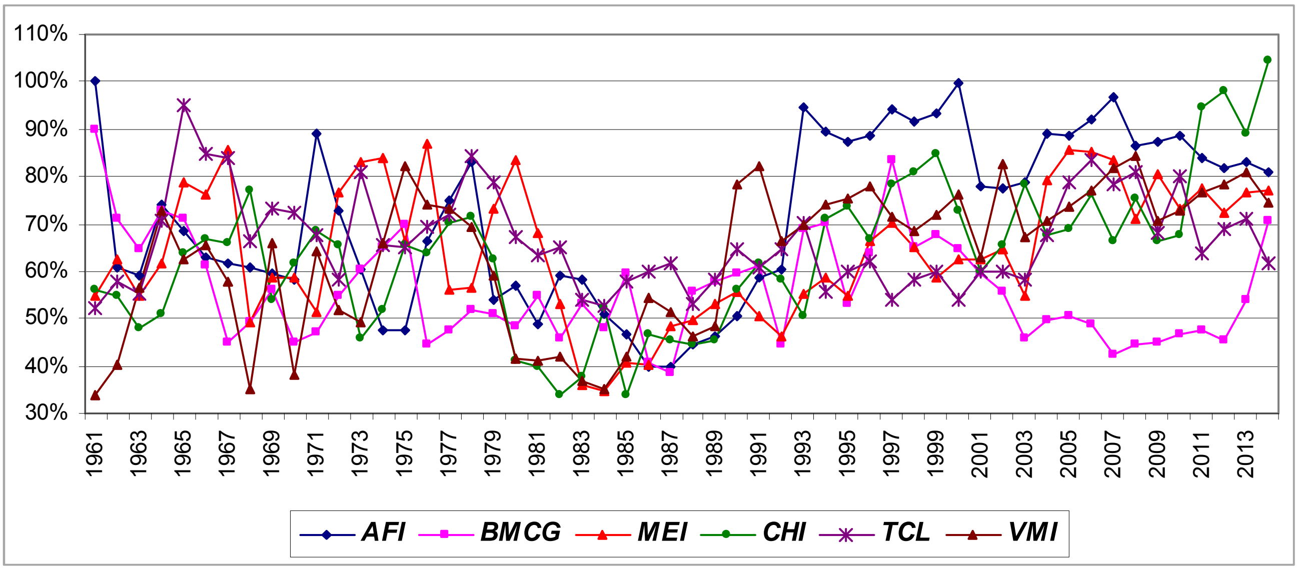

Figure 4. *Capacity utilization evolution per sector relative to Y_m.*

Table 2. *Cost function assessment.*

Variables	Value	Standard Deviation	t-statistic	p-value
α_0_AFI	3.67	0.37	9.90	0.000
α_0_BMCG	4.48	0.36	12.43	0.000
α_0_MEI	3.94	0.37	10.67	0.000
α_0_CHI	4.95	0.36	13.79	0.000
α_0_TCL	3.49	0.37	9.37	0.000

Variables	Value	Standard Deviation	t-statistic	p-value
α_0_VMI	3.09	0.37	8.32	0.000
β_K	-0.36	0.173	-2.07	0.038
β_Y	1.15	0.139	8.26	0.000
α_E	0.92	0.068	13.36	0.000
α_L	0.08	0.068	13.36	0.000
δ_{EE}	0.019	0.025	0.75	0.455
δ_{LL}	0.019	0.025	0.75	0.455
δ_{LE}	-0.019	0.025	-0.75	0.001
γ_{KK}	0.31	0.047	6.55	0.000
γ_{YY}	0.38	0.31	12.18	0.000
ρ_{YK}	-0.43	0.031	-13.59	0.000
ρ_{YL}	0.30	0.015	20.31	0.000
ρ_{YE}	-0.30	0.015	-20.31	0.000
ρ_{KL}	-0.15	0.014	-10.79	0.000
ρ_{KE}	0.15	0.014	10.79	0.000
α_t	-0.09	0.02	-4.67	0.000
γ_{tt}	-0.003	0.0004	-9.13	0.000
ρ_{tY}	0.03	0.002	11.95	0.000
ρ_{tK}	-0.002	0.004	-0.58	0.559
ρ_{tL}	-0.004	0.001	-3.11	0.002
ρ_{tE}	0.004	0.001	3.11	0.002

Notes: OGR: Agriculture and Food Industry (AFI), Building Materials, Ceramics and Glass (BMCG), Mechanical and Electrical Industries (MEI), Chemical industries (CHI), Textiles, Clothing and Leather (TCL), Various Manufacturing Industries (VMI).

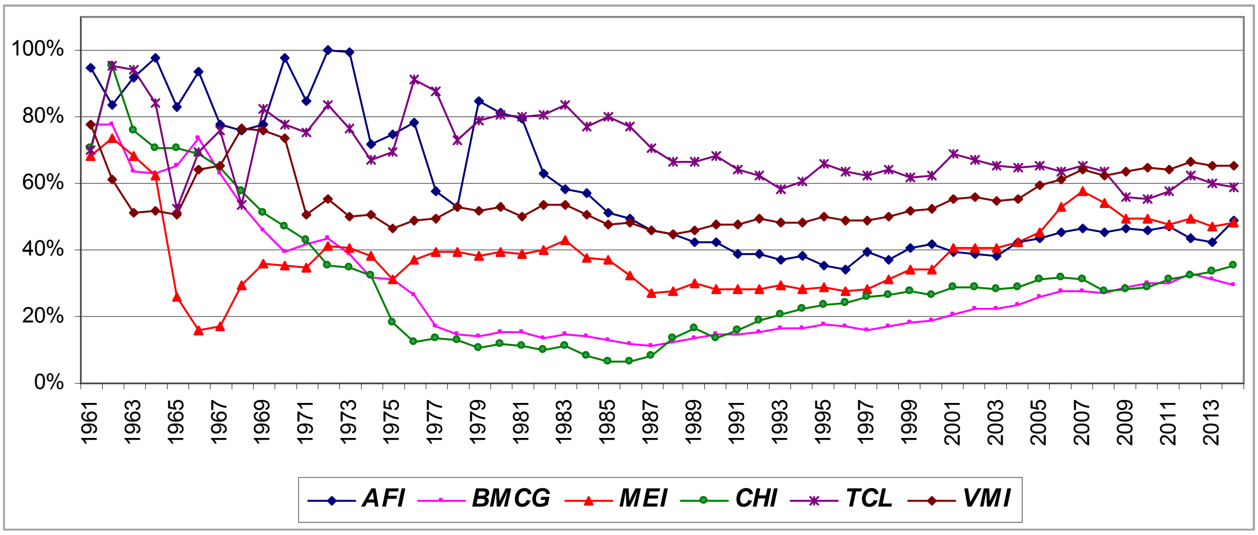

Figure 5. *Capacity utilization evolution per sector relative to Y_t.*

Considering the NCRS Translog variable cost function results, all the estimates can be evaluated depending on the production capacity estimated values. Two primal estimates were found. However, there is still a strong divergence of the results for the six sectors. Moreover, the AFI and TCL strong values can still be noticed compared to the other sectors.

Moreover, referring to Figures 4, 5 and 6, the CU_m evolution is almost greater than that of the CU_t, which shows that the Tunisian economy is characterized by under-utilization of the production capacity where the declining returns to scale can be noticed most of the time. Actually, the dominant sectors are the AFI and TCL, which reflect the highest capacity utilization rates during the 1961-2014 study period. On the other hand, the BMCG, CHI and VMI sectors recorded the lowest values. A general glance at the above figures also shows an expansion phase during the beginning of the 1961/1979 period followed by a recession phase between 1980 and 1989, when the lowest rates were recorded. Following the 1980 crisis, most of the series went upward to reach average measures of around 97.2% for the AFI in 2007 followed by a slight fall due to the effect of the financial crisis during the same period (see Table 3).

In total, the manufacturing industrial sector uses an average of 63.2% of its resources for the first measure and 57.6% for the second with associated standard deviations of 8.8% and 8.2%, respectively. Therefore, based on the NCRS Translog cost function, the industrial sector is found in an average underutilization of the production factors, which results in a technical efficiency. At the same time, the CU_D dual measurement, of which the per-sector evolution is defined in Figure 7, is assessed.

The *CU* results, as an efficiency measure of the Tunisian manufacturing sector, show very high values close to the unit. This means that there is an average underutilization of the production capacity during the 1961/2014 study period. At the beginning of the period and for most of the sectors, the dual measurement represents a great underutilization sometimes equal to 100%. Through an NCRS analysis, from the 1980s, the overall costs became closer to the optimal costs. This led to dual measures very close to the unit at the end of the period. In general, the dual measure has an average of 76%. In addition, there is a strong divergence of the primal and dual results.

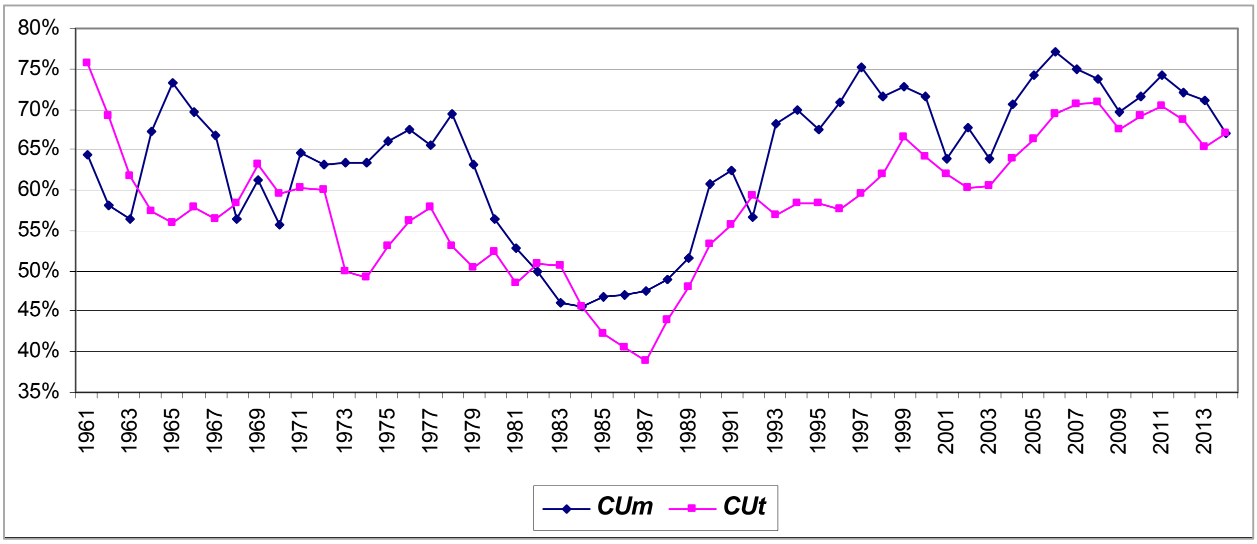

Figure 6. *Average capacity utilization evolution.*

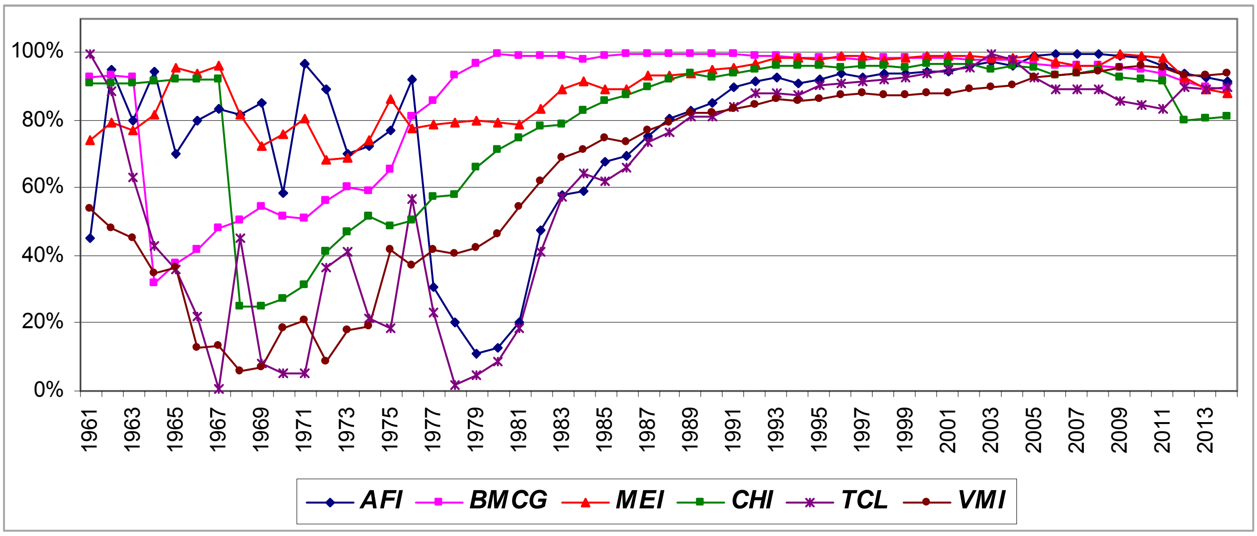

Figure 7. *Dual capacity utilization evolution per sector.*

Table 3. *Descriptive analysis of the capacity utilization (%).*

CU_m	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
Minimum	39.94	38.76	34.77	33.80	52.40	33.70	45.66
Maximum	100.00	90.00	86.80	84.90	94.95	84.40	77.08
Average	70.23	56.24	63.34	60.63	66.52	62.22	63.24
Standard Deviation	17.74	11.16	14.11	12.81	10.36	15.04	8.82
OGR %	-11.4	-48.2	34.1	20.6	53.0	115.4	10.9
AAGR %	-0.2	-1.3	0.6	0.4	0.9	1.6	0.2
CU_t	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
Minimum	40.33	31.46	33.32	21.68	43.08	32.54	38.78
Maximum	94.87	68.61	82.13	83.40	82.91	74.88	75.74
Average	62.91	54.88	63.76	53.81	63.05	46.94	57.56
Standard Deviation	13.08	8.46	11.48	14.15	11.04	9.68	8.22
OGR	11.3	-8.7	3.0	-17.0	-18.8	-18.9	-8.6
AAGR	0.2	-0.2	0.1	-0.4	-0.4	-0.4	-0.2

CU_m	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
CU_D	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
Minimum	11.0	31.9	68.5	24.6	0.6	5.7	39.5
Maximum	99.8	99.7	99.5	96.5	99.7	96.0	96.3
Average	77.9	85.8	89.2	80.0	61.4	62.1	76.0
Standard Deviation	24.2	20.7	9.8	22.2	33.3	29.5	19.2
OGR	118.4	2.0	33.1	1.1	-15.4	78.0	23.5
AAGR	1.6	0.0	0.6	0.0	-0.3	1.2	0.4

Notes: OGR: the overall growth rate; AAGR: the average annual growth rate. Tunisian manufacturing industry (TMI), Agriculture and Food Industry (AFI), Building Materials, Ceramics and Glass (BMCG), Mechanical and Electrical Industries (MEI), Chemical industries (CHI), Textiles, Clothing and Leather (TCL), Various Manufacturing Industries (VMI).

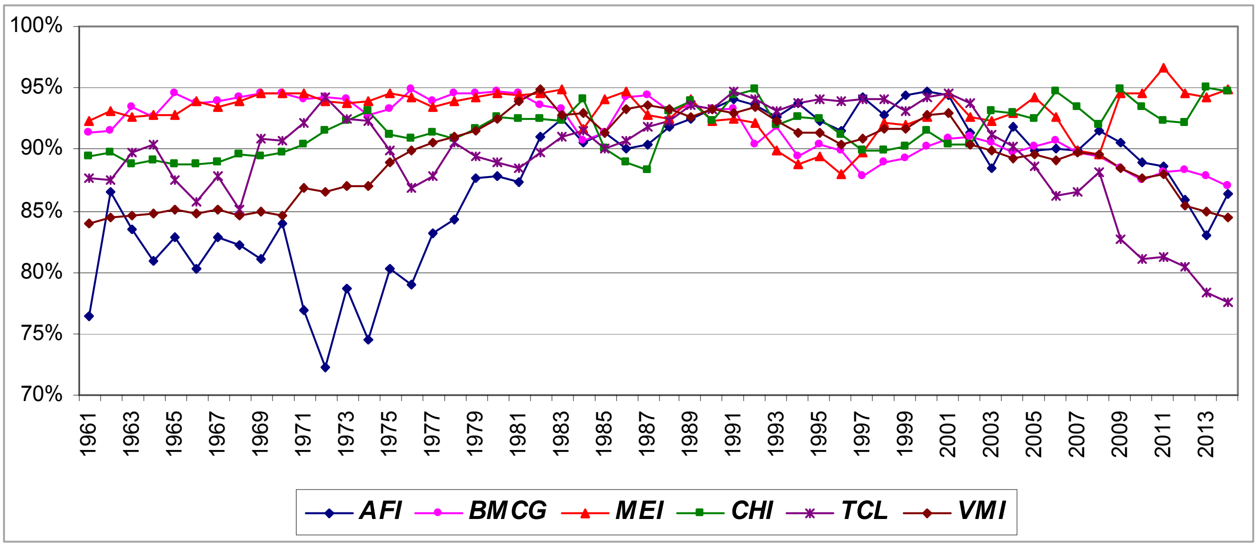

Figure 8. *Sectoral evolution of technical efficiencies.*

For the efficiency scores estimation derived from the Translog variable cost function at NCRS, we use the method of moments. Estimates of these technical efficiencies are illustrated in Figure 8, showing the evolution of the efficiency of the various sectors of the manufacturing industry over time.

The results show that the sectors efficiencies evolved at an average rate, except for the AFI sector which efficiency went through two important phases. The first, dating back from 1961 to 1991, shows an upward trend, while the second, which began in 1991, shows a slight decline to reach a score of 95% (see Table 4). For the other sectors, the evolution is on average between 81 and 95%. It should be noted that the different sectors efficiency decreased at rates close to 70%. In total, the TMI shows an average annual inefficiency of 13% with a standard deviation of 1.7%.

Regarding the measurement of the short- and long-run elasticities, the main results are presented in Table 4 (average values per sector). At NCRS, the production capacity elasticity ($\varepsilon_{Yi}^{SR} = -\varepsilon_{Ki}^{LR}$) is positively related to labor and energy prices, with the exception of the BMCG sector. The production capacity showed a greater sensitivity to the labor price. The positive sign of $\varepsilon_{YE}^{SR} = -\varepsilon_{KE}^{LR}$ is compatible to a certain degree of complementarity between Capital and Energy in the long run. However, there seems to be evidence of a significant long-run substitutability between capital and labor. The increase in energy prices tends to slightly increase the long-run capital demand as this leads to an increase in production.

Table 4. *Mean values estimated elasticities.*

Elasticity	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
ε_{YL}^{SR}	0.307	0.264	0.392	0.284	0.491	0.349	0.390
ε_{YE}^{SR}	0.272	-1.074	-0.070	-0.202	0.053	0.210	0.250
σ_{LE}^{SR}	0.406	0.582	0.422	0.547	0.164	0.355	0.452
σ_{EL}^{SR}	0.475	0.315	0.432	0.195	0.619	0.542	0.456
σ_{LL}^{SR}	-0.406	-0.582	-0.422	-0.547	-0.164	-0.355	-0.452
σ_{EE}^{SR}	-0.475	-0.315	-0.432	-0.195	-0.619	-0.542	-0.456
ε_{KK}^{LR}	0.744	-0.419	0.500	-0.447	0.207	0.340	0.332

ε_{KL}^{LR}	-0.295	-0.427	-0.342	-0.385	-0.214	-0.232	-0.249
ε_{KE}^{LR}	-0.115	0.475	0.158	0.491	0.104	-0.180	0.060
ε_{LK}^{LR}	0.307	0.264	0.392	0.284	0.491	0.349	0.390
ε_{EK}^{LR}	0.272	-1.074	-0.070	-0.202	0.053	0.210	0.250

Note: Tunisian manufacturing industry (TMI), Agriculture and Food Industry (AFI), Building Materials, Ceramics and Glass (BMCG), Mechanical and Electrical Industries (MEI), Chemical industries (CHI), Textiles, Clothing and Leather (TCL), Various Manufacturing Industries (VMI).

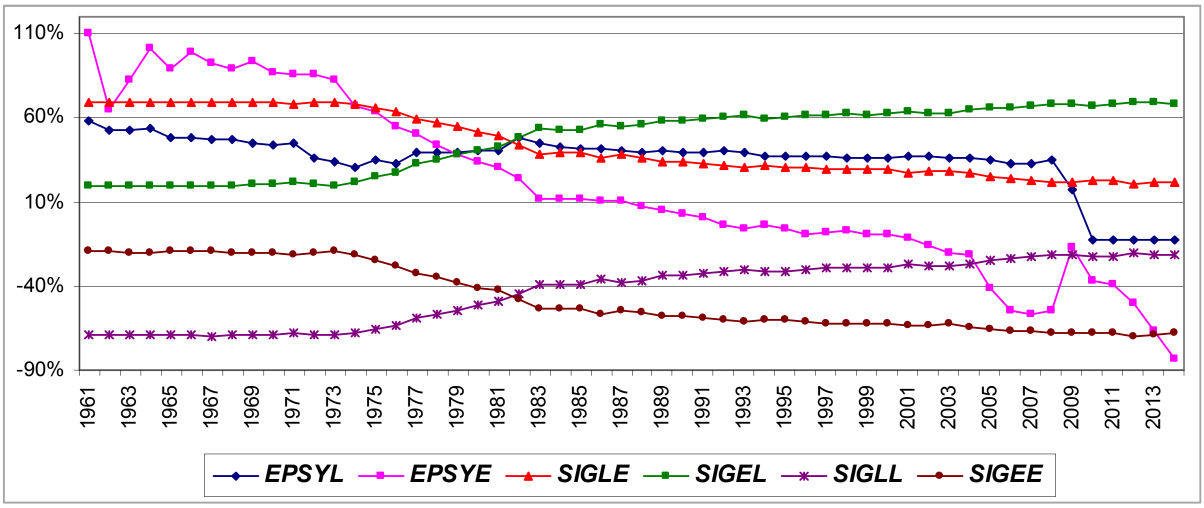

Figure 9. *Short-run elasticities average evolution.*

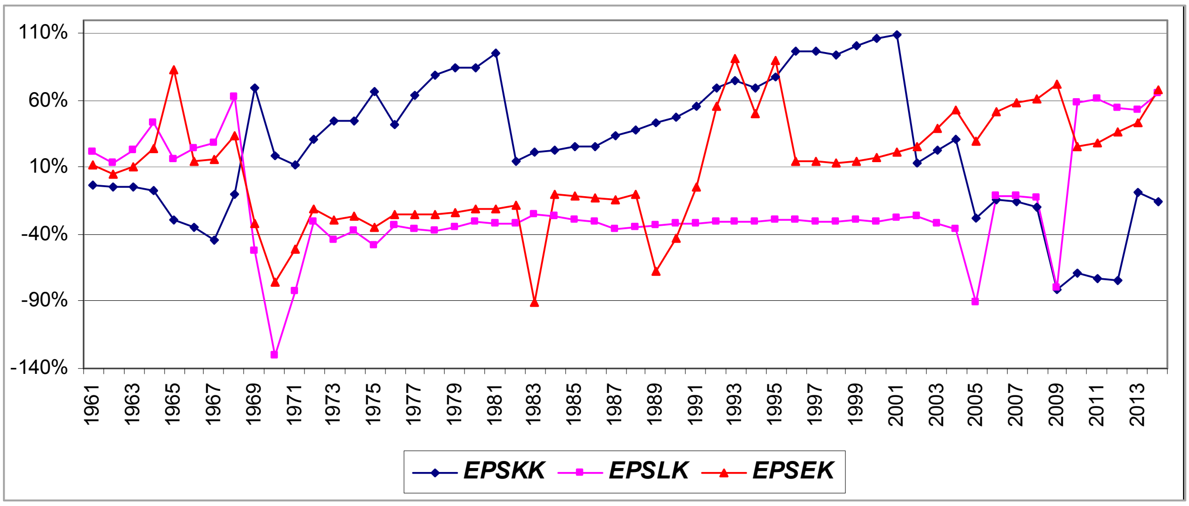

Figure 10. *Long-run elasticities average evolution.*

The sector analysis (Figures 9 and 10) shows that the short-term elasticities are on average low and below 1, which means that there is not a strong sensitivity to changes in the variable factors in the production capacity. Similarly, this phenomenon is the same in the long-term and the sensitivity is not strong enough. Thus, the factors demand will be slightly affected by the level of capital and production capacity.

3.3. The Total Factor Productivity Estimation and Interpretation

The estimation of the above cost function helps to deduce an analysis in terms of total factor productivity for the Tunisian manufacturing industry over the study period. For the macroeconomic situation of Tunisia, which has substantially changed over the study period, we distinguish two essential periods in our analysis: from 1961 to 1987, during this period Tunisia had a strong economic turbulence that practically affected all the industries. From 1988 to 2014, this period was characterized by a return to stability and economic growth. Table 5 below summarizes the values of the primal TFP estimates (ε_{Yt}) and dual (ε_{Ct}) from the Translog average variable cost.

In general, a substantial amount of the productivity decline is evident between 1961 and 1987. In fact, the objective of such an adjustment, to estimate productivity, is to measure the sub-balance. The empirical significance of this adjustment given in Table 6 by the average annual growth rate of ε_{Ct}^{LR}, differs across sectors.

Over time, the above results reveal a modest decrease in the dispersion of productivity measures with the adjustment of the sub-balance. In addition, the 70's and 80's still appear as a period of low productivity and the two years after 1973 seem even more catastrophic because of the great-unexpected shocks. In 1973, the average annual growth rate was negative. This period could be a strong candidate for the title of "productivity growth slowdown" due to the oil crises during that period.

Table 5. *Estimated productivity mean values (%).*

TFP measure	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
ε_{Yt}^{SR}	0.0	-0.3	-0.1	-0.5	-1.7	-0.9	-0.6
ε_{CK}^{LR}	-31.1	50.7	60.5	36.9	18.4	38.5	42.6
ε_{Yt}^{LR}	0.7	0.6	-0.4	-4.9	-5.6	-4.9	-2.4
ε_{Ct}^{SR}	9.2	5.7	1.2	12.5	14.5	9.7	8.8
ε_{Ct}^{LR}	-16.4	13.8	2.7	26.3	-29.3	-5.5	-1.4
η_k	29.6	57.3	44.2	43.6	79.6	34.7	48.2
CU_D	70.8	77.3	83.1	83.4	83.0	84.5	80.4

Note: Tunisian manufacturing industry (TMI), Agriculture and Food Industry (AFI), Building Materials, Ceramics and Glass (BMCG), Mechanical and Electrical Industries (MEI), Chemical industries (CHI), Textiles, Clothing and Leather (TCL), Various Manufacturing Industries (VMI).

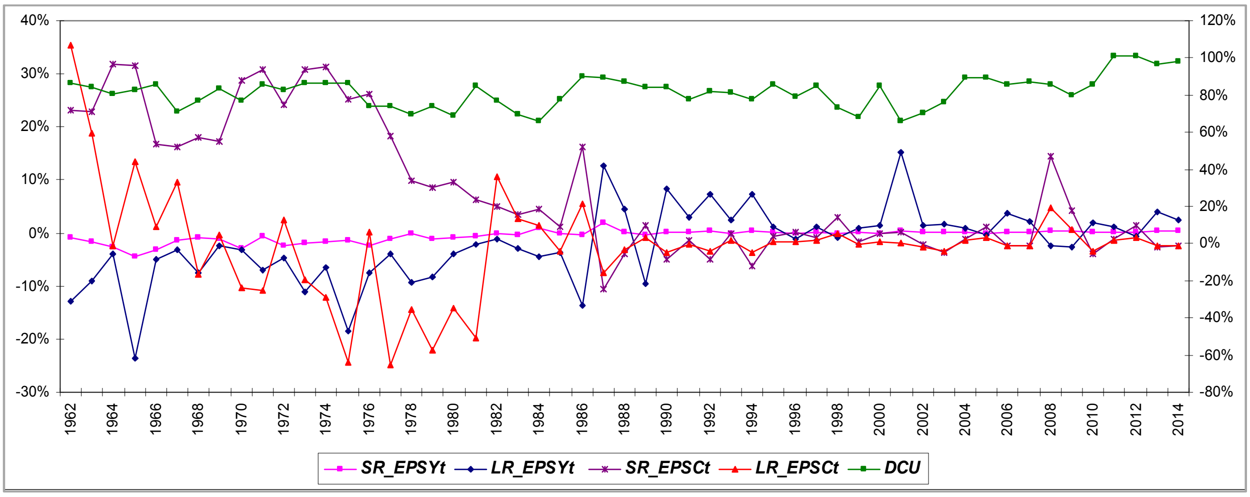

Figure 11. *Primal and dual total factor productivity measures.*

A great productivity change appears to have occurred before 1987. For the first measurement, ε_{Ct}^{LR}, the average annual growth rate decreased by 13% between 1971-1980. However, it dropped to 30% between 1980 and 1987. Regarding the second productivity growth measurement, ε_{Yt}^{LR}, the evolution is more stable. We can see an average drop of 1.5% and 2% from 1971 to 1980 and 5.7% and 6.5% between 1980 and 1987. This seems to be due to the considerable decline of productivity especially in 1987 with a rate between 0.9% and 2.6%.

As shown in Figure 11, we can see a downward trend in both of the capital productivity growth rate and the total factor productivity over the period 1985-2014. Furthermore, the scale efficiency growth is, most of the time, enough to generate an overall productivity increase. The liberalization of the Tunisian market has certainly contributed to the increase of the value-added businesses by enabling growth and consolidation to continue.

3.4. Further Comments on Results

The evaluations of the different average annual growths in productivity are shown in Table 6. First, since this growth rate decreased along the study period, we can increase productivity by exploiting economies of scale. The three alternative estimates indicate that there was a rapid productivity drop of 17% between 1961 and 2014 and 2.8% in the *CU*. This implies the existence of decreasing returns to scale throughout the study period although there were increasing returns to scale just at the beginning of the period (1961-1971) and an improvement that started from 1998.

From 1970 to 1980, the production decrease was greater than that of the inputs, which resulted in a slowdown of returns by 3% per year accompanied by a similar decline of the average of *CU*. At this quantitative level, the economy faced diseconomies of scale. Between 1980 and 1987, the decline of the input growth outpaced production. This resulted in improved returns at a low positive rate of 0.3%

but had no effect on the *CU* growth, which remained low at an annual rate of 3%.

Table 6. *Annual growth rate different productivities (%).*

PTF	AFI	BMCG	MEI	CHI	TCL	VMI	TMI
ε_{Yt}^{SR}	-8.93	-19.84	-19.83	-19.29	-19.30	-19.15	-17.72
ε_{Yt}^{LR}	-19.56	-20.07	-20.39	-19.59	-19.25	-19.37	-19.70
ε_{Ct}^{SR}	-19.48	-19.85	-19.83	-19.67	-19.74	-19.46	-19.67
ε_{Ct}^{LR}	-2.85	-19.15	-19.34	-19.28	-19.30	-7.84	-14.63
CU_D	6.20	-1.00	-5.80	8.01	-4.30	-5.13	-2.80

After 1987, two important events occurred. Between 1987 and 1991, the production factors grew faster than the output. Thus, diseconomies of scale persisted. Paradoxically, we remark an increase in the *CU* with the same proportion. This means that the marginal cost continues to increase (the more we produce, the more expensive it is to produce an additional unit) because this requires more factors to produce one unit. After 1991 and before 2001, the change of the output was less important than the used production factors.

Over the entire period, the productivity increase was about 1% per year, with a standard deviation of 0.37. Our estimates of productivity growth, based on the total variable cost function are considerably less than the unity. The estimated total cost function involves a small change of the production structure, but at a medium scale.

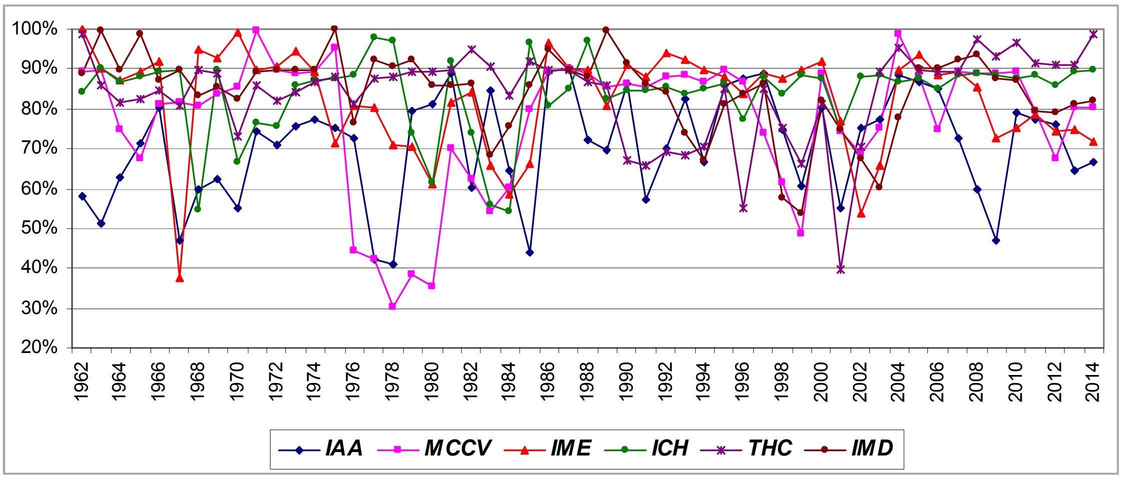

Figure 12. *Dual evolutions of capacity utilization from the total factor productivity.*

Between 1991 and 2000, there was a low productivity growth accompanied by a *CU* increase mainly due to the various economic and geopolitical problems. In general, these are the results of a rather substantial total effect of the productivity decline over the period 1961-2014 but would not have conclusive evidence of a single sudden slowdown in productivity growth before 1973 or 1987 in the Tunisian industry.

The different *CU* dual measures (Figure 12) show the empirical equivalence between the estimation results through the Translog cost function and the one through the total factor productivity definition. Actually, the same trends and developments are noticed throughout the study period characterized, first, by an under-utilization of the production capacity, and secondly, by a decline of productivity, which means that there is a slowdown in the productivity growth.

However, the main factor in improving productivity remains that of *TFP*. This contribution stems from the overall improvement in the performance of the company and its institutions, allowing better utilization of the country's available capacity. Taking into account the contribution of factor quality (0.6-0.7%), that of *TFP* is estimated at 1.4% annual growth over the period 1990-2014. Although respectable, this contribution remains well below what has been observed in the successful countries.

Tunisia needs to see *TFP* growth reach 2.5% or more, requiring extensive reforms, the most important of which are: reform of state institutions, especially administration and decentralization; reform of labor relations and the labor market; better integration into the global economy in order to acquire better technology; reform of foreign trade and exchange rate regimes; sectoral reforms, such as in agriculture, tourism or industry; urban reforms.

Tunisia has to review its economic policies for the economic take-off to become possible. The country might opt for going on with the same state driven model, which is highly vulnerable to the extraction of rents, or go in the steps of other upper- and middle-income countries that recorded a better performance than that of Tunisia during the last two decades, favoring a true integration in the world economy.

The new model should discard privileges, open up economic opportunities for all Tunisians and increase prosperity across the country. This requires abandoning the idea of a welfare state, which helped give rise to patronage and privilege in favor of the elites. It had better move to a system where the state works to establish and enforce fair rules promoting the individual initiative and providing a targeted and effective support to the most disadvantaged (see [1, 2, 28, 20]).

4. Conclusion and Discussion

This study identified some important conclusions. In fact, the results of the estimates, either of the capacity utilization or the technical efficiencies of the six sectors, showed indexes below the unity and sometimes too low. This implies that there is a strong under-utilization of the production capacity of the Tunisian manufacturing sector. Moreover, the economy is shown to be represented by an inefficient industrial policy resulting in (decreasing) non-constant returns to scale through the 1961-2014 study period where the scale of elasticity associated with the dominant specification was estimated at 36.9%. This result is in compliance with a structure of a perfectly competitive market, which is not surprising given the number and size of the sectors. However, the fact that the size of the elasticity is low can be attributed mainly to the difficulties in assessing the unused capacity under the supply management policy.

The wide gaps in productivity across sectors suggest that the reallocation of low productivity sectors workers to other high productivity sectors can be an important growth factor. In fact, in several high-growth countries, particularly in Asia, the reallocation of workers across sectors contributed positively to growth over the last twenty years.

The Tunisian economy needs to grow faster than the recent years' pace in order to reduce unemployment substantially. Speeding up economic growth and job creation will require increased investment. Although Tunisia still has some room to increase the public investment level and improve its efficiency, there are still some ultimate inherent limitations to a development favoring growth in public investment. Liberalizing private investment thus emerges as the greatest challenge to accelerate sustainable growth and job creation in Tunisia. Tunisia is therefore at a crossroads at present and urgently needs a new development model.

The achievement of an overall growth rate of around 5-6% per year is possible in Tunisia, but this requires extensive and often difficult reforms. These reforms should make it possible to achieve an increase in labor productivity to reach 4-4.5% per year, with a contribution of the same magnitude to both the increase in capital intensity and investment and of total factor productivity.

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