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Full length research

Direct and indirect measures of capacity utilization and Economic growth: A nonparametric analysis of the Tunisian industry

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In this paper, we suggest a measure of the short run capacity utilization rates based on a reduced version of the indirect production function of Shephard. More precisely, we define the production capacity as the maximum quantity produced by the firm given the specific quantity of the quasi-fixed input and the overall budget constraint for its choice of variable inputs. The present study extends the non-parametric literature by modeling the indirect production function (restricted and unrestricted) and derives a measure of the capacity utilization rate using the DEA. We used annual data on time series on the overall output as well as the quantities and prices of the inputs published by the Tunisian Institute of Competitiveness and Quantitative Studies to measure the capacity utilization rate in the manufacturing industry for the period 1961-2010. Our empirical analysis aims to show the important variations in the capacity utilization both across industries and, over time, within the manufacturing industry.

Keywords: Data envelopment analysis, capacity utilization, indirect production function.

JEL Classification: D24, C13, C14, C15, C43, L6.

INTRODUCTION

The production capacity of a firm can be defined in several alternative ways. It represents the optimal physical limit measuring the maximum amount of output that the firm can produce from a given set of quasi-fixed input data, even if other inputs are available without any restriction. According to Johansen (1968), this definition is intuitively very interesting. Moreover, even when labor, raw materials and energy are available in limited quantities, the firm can only produce a certain amount of the whole production. The real produced output must be less than or equal to this production capacity. The capacity utilization rate (CU) is simply the ratio of its actual output at the level of the production capacity. In fact, this ratio depends on several factors. A capacity utilization rate less than the unit may be due either to a lack of demand faced by the firm being encouraged to restrict the output to a lower level of production capacity, or because of the lack of certain essential inputs, such as energy, which hinders production even if there is a sufficient demand for this product.

Since we consider the long run average total cost, no input is held fixed. For a firm with a typical U-shaped average cost curve, the economies of scale have been used up but the diseconomies have not yet set into play at this capacity of production. Thus, this physical limit defines the capacity of one or more quasi-fixed inputs. In addition, the economic measure is related to the capacity utilization of all the factors, fixed and variable, of the production.

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Klein (1960), supported the idea that the long run average cost curve cannot have a minimum, and hence he proposed that the maximum level of production has to be one where the short run average total cost curve is tangent to the long run average total cost curve as an alternative measure of production capacity (This is also the approach adopted by Berndt and Morrison, 1981). If technology exhibits constant returns to scale, the long-run average total cost curve is horizontal and the production capacity level is not defined. However, in this case, at this minimum point, the short run average total cost curve is tangent to the long run one. This helps to determine the short run level of economic production capacity and provides a measure of the capacity utilization of fixed input.

One of the empirical problems with this measure is that the short-run total cost at this level of production may exceed the short-run firm's budget. In the neoclassical theory, a firm, unlike a consumer, does not face a budget constraint. It is postulated to choose any possible input-output combination as long as production generates enough revenues to cover expenditure on the short run variable inputs. This, however, is an incorrect description of the real situation encountered by a typical firm. There are so many reasons why a firm wishes to stay within a short run budget limit.

Given that equity and credit are the two main sources of funds for the firm and equity capitals are difficult to obtain in the capital market in the short run, borrowing remains the only effective way to finance additional expenditure. Nevertheless, this could affect the firm in different ways. Firstly, a higher debt ratio could cause the market to consider the firm more risky, which in turn would affect its valuation. Second, borrowing on short notice is more likely to be at unfavourable interest rates. A quasi-fixed input is maintained constant in the short run due to the adjustment costs. Comparably, the firm would maintain its total operating expenses within the budgetary limit and avoid excessive costs of credit and adverse market reaction.

The idea of expenditure constraints and their impact on the production decisions is not entirely new. Shephard (1953, 1970 and 1974), presented a detailed discussion on the theory of indirect production. The concept of the cost indirect production technology was introduced into the mainstream literature by Ferguson (1969). In the context of the United States agriculture, Lee and Chambers (1986), have empirically tested the effect of the expenditure-constraint on the profit maximization of farms. Their results reject the hypothesis of unconstrained profit maximization while expenditure-constraint profit maximization cannot be rejected. However, and according to Ray et al. (2005), budgetary constraints have not been incorporated into the measurement of the capacity utilization and have not been included in the same analysis of productivity and efficiency in the industrial context.

In this work, we propose a measure of short run production capacity and the associated capacity utilization rate based on a restricted version of the indirect production function of Shephard (1970). More precisely, we define production capacity as the maximum quantity that can be produced by the firm given a specific amount of quasi-fixed input and overall budget constraint for its choice of the variable inputs. We assume that the firm is authorized to use any set of variable inputs within a global constraint on expenditure. In effect, it is a restricted version of Johansen's concept of physical capacity. In addition, this work will explicitly take into account the relative prices of the variable inputs. Färe et al. (1989), (FGK) provide a nonparametric model using Data Envelopment Analysis (DEA) to measure the physical production capacity and the associated capacity utilization rates in the presence of fixed inputs. Thus, this study extends this line of nonparametric literature by modelling the (with or without constraints) indirect production function and derives a measure of capacity utilization using the DEA methodology.

This paper is developed as follows. In the first section, we provide the theoretical framework to explain the conceptual problems where we describe the nonparametric DEA methodology. The second section presents the empirical analysis and interpretation results. The last part is devoted to conclusions and perspectives.

The theoretical backgrounds

Conceptual issues

Let us consider an m-output, n-input production technology. An input-output combination (x, y) is a feasible production plan if output set y can be produced from input set x. The set of all the feasible production plans constitute the production possibility set

$$T = \{(x, y),\ \ y \text{ can be produced from } x\} \qquad (1)$$

In the single output case, the production function is defined as

$$f(x) = \max y : (x, y) \in T \qquad (2)$$

If we assume that the inputs are freely available, then

$$(x, y) \in T \text{ and } x' \geq x \text{ together imply that } (x', y) \in T \qquad (3)$$

If we assume that the outputs are freely available, then

$$(x, y) \in T \text{ and } y' \leq y \text{ together imply that } (x, y') \in T \qquad (4)$$

Then the maximum production producible from any specific input set x^0 is

$$y_0^* \in f(x^0) = \max y : x \leq x^0, (x^0, y) \in T \qquad (5)$$

The technical efficiency of a firm producing output y^0 from input x^0 is:

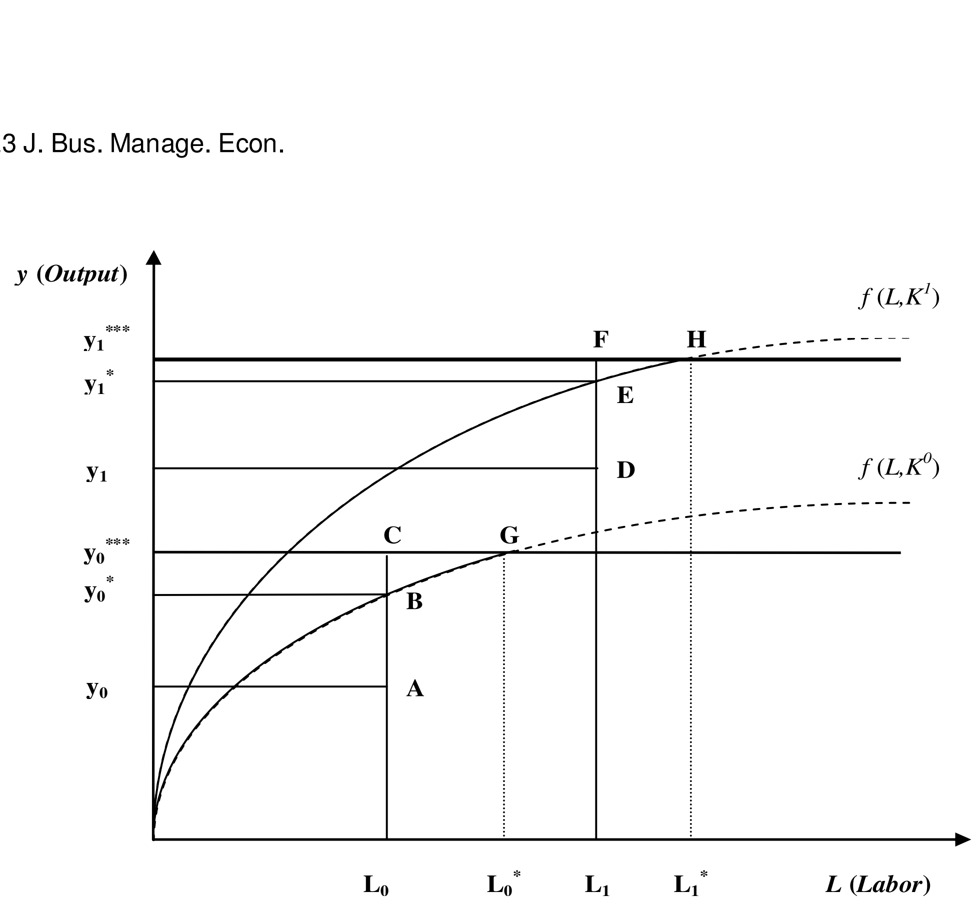

Figure 1. Direct Measure of Capacity utilization. (Source: Ray et al., 2005, p.29).

$$\tau\left(x^0, y^0\right)=\frac{y^0}{y_0^*}=\frac{y^0}{f\left(x^0\right)} \tag{6}$$

Now, we suppose that input vector x can be partitioned as x= (v, K) where v is a sub-vector of the variable inputs and K is a vector of quasi-fixed inputs. Johansen (1968) defined the capacity level of the output as the maximum quantity that can be produced from a specific set of quasi-fixed inputs even when the variable inputs are available in unrestricted quantities. Thus, for the quasi-fixed input set K^0, the production capacity is

$$y^C\left(K^0\right)=\max y:(v,K,y)\in T, K\leq K^0, v\geq 0 \tag{7}$$

The capacity utilization rate is

$$CU=\gamma\left(K^0\right)=\frac{f\left(x^0\right)}{y^C\left(K^0\right)}=\frac{f\left(v^0,K^0\right)}{y^C\left(K^0\right)} \tag{8}$$

It may be noted that this will differ from the ratio of the actual output to capacity output when technical efficiency (τ) is lower than the unity.

Then, we consider the input price vector u = (w, r), where w is the sub-vector of prices of the variable inputs (v) and r is the price vector of the quasi-fixed inputs (K). Then the cost of the observed input set is actually

$$C^0=w'v^0+r'K^0 \tag{9}$$

Following Shephard (1970), for the input prices (w, r) and an expenditure budget C, the cost-indirect production function can be defined as

$$g(w,r,C)=\max\ y:(v,K,y)\in T,\ w'v+r'K\leq C \tag{10}$$

thus,

$$g(w,r,C)=\text{Argmax } f(v,K):\ w'v+r'K\leq C \tag{11}$$

Here g(w, r, C) is the maximum output the firm can produce from an input set affordable within its budget. In (11) above, the firm is free to choose both v and K within its overall expenditure constraint. However, when K is quasi-fixed at K^0 in the short run, we get the restricted version of the indirect production function as

$$h\left(w,CV^0,K^0\right)=g\left(w,CV^0\middle|K^0\right)=f(v,K):w'v\leq CV^0;K\leq K^0 \tag{12}$$

Here $VC^0 = C^0 - r'K^0$. Note that $r'K^0$ is the fixed cost. Even though the firm may choose to use less than the total available quantity of the fixed input, this does not give any part of the fixed cost to be spent on the variable inputs.

An indirect measure of capacity utilization for the quasi-fixed input K^0, the input prices w and the actual variable cost VC^0 is

$$\psi\left(w,CV^0,K^0\right)=\frac{f\left(v^0,K^0\right)}{h\left(w,CV^0,K^0\right)} \tag{13}$$

In fact, figures 1, 2, and 3 illustrate the different capacity utilization concepts described below.

The total product curves in figure 1 show the maximum quantities of output from different quantities of labor (L) when equipped with two different quantities of the quasi-fixed input (K^0 and K^1). For K equal to K^0, the total output increases with L (up to L_0^*) along the OBG segment of the f(L, K^0) curve. Thereafter, an increase in labor does

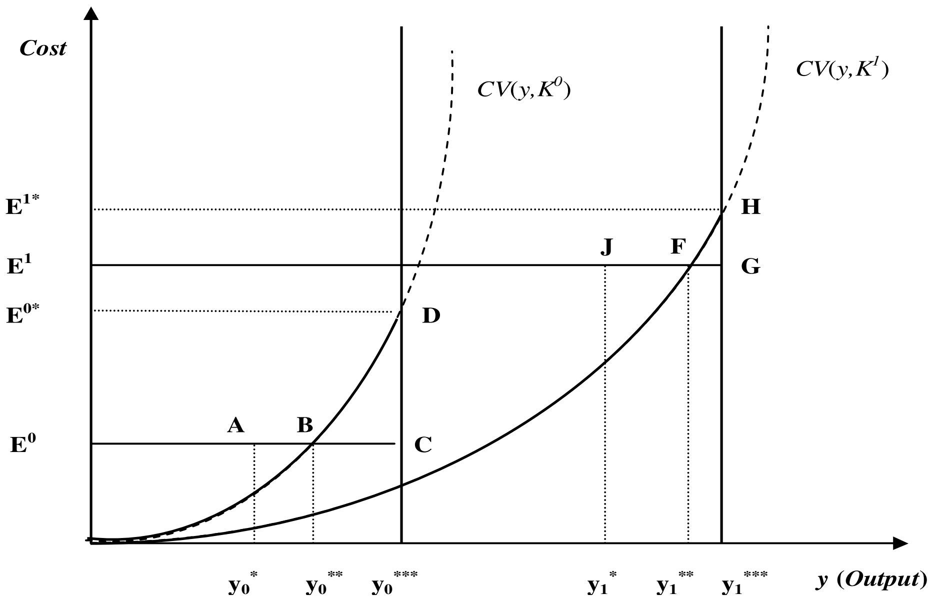

Figure 2. Indirect Measure of Capacity utilization (Source: Ray et al., 2005, p.30).

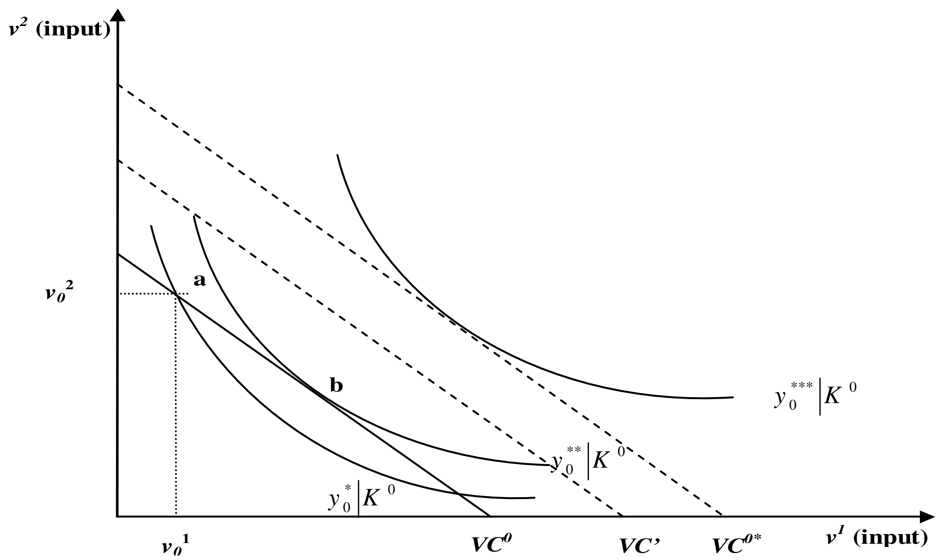

Figure 3. Interpretation of Indirect Measure of Capacity Utilization (Source: Ray et al., 2005, p.31).

not lead to a higher level of output. It remains constant at $y_0^{***} = f\left(L_0^{*}, K^0\right)$. Thus, the efficient output is

$$y_0^{*} = \min\left\{f\left(L, K^0\right); y_0^{***}\right\} \qquad (14)$$

Hence, y_0^{***} is the production capacity for the quasi-fixed input level K^0.

Similarly, for the higher level of the quasi-fixed input K^1, the total product curve becomes horizontal at point H once L has increased to L_1^{*} and

$$y_1^{*} = \min\left\{f\left(L, K^1\right); y_1^{***}\right\} \qquad (15)$$

where

$$y_1^{***} = f\left(L_1^{*}, K^1\right) \qquad (16)$$

is the capacity output level for K^1. Suppose that a firm is producing output y_0 from the input set (L_0, K^0), shown by point A, its technical efficiency is

$$\tau_0 = \frac{y_0}{y_0^*} = \frac{AL_0}{BL_0} \quad (17)$$

whereas the direct measure of capacity utilization (DIRCU) is

$$DIRCU_0 = \frac{y_0^*}{y_0^{***}} = \frac{BL_0}{CL_0} \quad (18)$$

Similarly, for output y_1 produced from the input set (L_1, K^1), the technical efficiency is

$$\tau_1 = \frac{y_1}{y_1^*} = \frac{DL_1}{EL_1} \quad (19)$$

and the direct measure of capacity utilization is

$$DIRCU_1 = \frac{y_1^*}{y_1^{***}} = \frac{EL_1}{FL_1} \quad (20)$$

The indirect capacity utilization measure can be explained using figures 2 and 3. The variable cost curves for the two different levels of the quasi-fixed input (K^0 and K^1) are shown in figure 2. The corresponding variable cost line and the isoquants in the variable input space for K_0 are shown in figure 3.

Figure 2 shows the total variable cost curves corresponding to the quasi-fixed input levels K^0 and K^1 for the single output case. Point A in the diagram shows the efficient output producable from some variable input set v_0 actually used by a firm that uses quasi-fixed input K^0. The corresponding variable cost is E^0. The variable input set actually used is shown by point A in figure 3 where the axes measure the quantities of the variable inputs v^1 and v^2. Note that it lies on the isoquant labelled $y_0^* \big| K^0$ as well as on the variable cost line VC^0. However, it is not on the highest reasonable isoquant on the VC^0 line (Note that VC^0 in figure ***3*** is equal to E^0 from figure ***2***). If the firm reallocates its expenditure appropriately and moves to point b on the same line VC^0, it can increase its production to y_0^*. This is the maximum output feasible from the quasi-fixed input K^0 without increasing the total variable cost. In figure 2, the corresponding point B on the total variable cost curve VC(y, K^0) shows the combination (y_0^{**}, E^0).

The indirect capacity utilization rate (INDIRCU) for output y_0 produced from input set (L_0, K^0) is

$$INDIRCU_0 = \frac{O\,y_0^*}{O\,y_0^{**}} = \frac{E^0 A}{E^0 B} \quad (21)$$

Similarly, the corresponding rate for output y_1 produced from input set (L_1, K^1) is

$$INDIRCU_1 = \frac{O\,y_1^*}{O\,y_1^{**}} = \frac{E^1 J}{E^1 F} \quad (22)$$

In figure 3, the comparison of points A and B leads to a measure of the indirect capacity utilization rate. If the reallocation of funds between the different variable inputs can lead to a significant increase in output, this indirect capacity utilization rate will be low.

Finally, the direct capacity production y_0^{***} is shown by the vertical line through C in figure 2 and by the isoquant $y_0^{***} \big| K^0$ in figure 3. As is apparent from figure 2, this output can be reached from the quasi-fixed input K^0 (at the point D) only by increasing the variable cost to E^{0^*}. The distance BC reflects the impact of the firm's short run budget constraint. A measure of the effect of the short run budget constraint (SRBC) when it is binding is given by the ratio

$$SRBC_0 = \frac{O\,y_0^{**}}{O\,y_0^{***}} = \frac{E^0 B}{E^0 C} \quad (23)$$

The distance CD measures the deficit in expenditure on the variable inputs while distance BC is a measure of the resulting under-utilization of capacity. The relationship between these two will depend on the marginal cost of the firm. When marginal cost is high, even with a large shortfall in expenditure, under-utilization of capacity would be low. In that case, the short run budget constraint (SRBC) factor will be closer to the unity. The opposite will be true when the marginal cost is lower.

The nonparametric methodology

We now describe the nonparametric methodology used in this paper to compute the direct and indirect measures of the capacity production.

Suppose that (x^j) = (v^j, K^j) is the observed set of variable and fixed inputs and y^j is the output set of firm j (j =1, 2, …, N) in the sample. Correspondingly (w^j, r^j) is the vector of input prices of firm j. Under the standard assumptions of convexity and free disposability of inputs and outputs, the production possibility set constructed from the data is

$$S = \left\{ (v, K, y) : \sum_{j=1}^{N} \lambda_j . K^j \le K ; \sum_{j=1}^{N} \lambda_j . y^j \ge y ; \sum_{j=1}^{N} \lambda_j = 1 ; \lambda_j \ge 0 ; j = 1,2,\ldots,N \right\} \quad (24)$$

Following Charnes et al. (1978), (CCR) for the input-output set (v^0,K^0, y^0), we have $y_0^* = \varphi^* y^0$, where

$$\varphi^* = \max \varphi$$

$$s.t. \sum_{j=1}^{N} \lambda_j . v^j \le v^0 ; \sum_{j=1}^{N} \lambda_j . K^j \le K^0 ; \sum_{j=1}^{N} \lambda_j . y^j \ge \varphi y^0 ; \lambda_j \ge 0 ; j = 1,2,\ldots,N. \quad (25)$$

Further, as shown by Färe et al. (1989) and Ray (2002),

$$y^C\left(K^0\right) = \varphi^C . y^0 \quad (26)$$

Where $\varphi^C = \max \varphi$

$$s.t.\ \sum_{j=1}^{N}\lambda_j.v^j \le v;\ \sum_{j=1}^{N}\lambda_j.K^j \le K^0;\ \sum_{j=1}^{N}\lambda_j.y^j \ge \varphi y^0;\lambda_j \ge 0; j=1,2,...,N. \quad (27)$$

In the above model, the constraint relating to the variable inputs is non-binding and could essentially be omitted.

For the indirect production function, we solve the following DEA model (Note that in model (*28*) C^0 is the budgeted Total Cost).

$$\delta^* = \max\delta \quad (28)$$
$$s.t.\sum_{j=1}^{N}\lambda_j.v^j \le v;\sum_{j=1}^{N}\lambda_j.K^j \le K;\sum_{j=1}^{N}\lambda_j.y^j \ge \delta y^0; w'.v + r'.K \le C^0;\ \lambda_j \ge 0; j=1,2,...,N.$$

The optimal solution for (28) yields the indirect production function,

$$g\left(w,r,C^0\right)=\delta^*.y^0 \quad (29)$$

Finally, we propose the restricted indirect production function introduced in (12) above as

$$h\left(w,CV^0,K^0\right)=\beta^*.y^0 \quad (30)$$

Where $\beta^* = \max\beta$

$$s.t.\sum_{j=1}^{N}\lambda_j.v^j \le v;\sum_{j=1}^{N}\lambda_j.K^j \le K^0;\ \sum_{j=1}^{N}\lambda_j.y^j \ge \beta.y^0;\ w'.v \le CV^0;\ \lambda_j \ge 0; j=1,2,...,N. \quad (31)$$

with $CV^0 = C^0 - r'.K^0$.

It can be seen from the structure of the relevant problems that

$$\varphi^C \ge \beta^* \ge \varphi^* \quad (32)$$

thus,

$$\gamma\left(K^0\right)=\frac{\varphi^*}{\varphi^C} \le \psi\left(w,CV^0,K^0\right)=\frac{\varphi^*}{\beta^*} \quad (33)$$

In other words, the indirect capacity utilization measure introduced here is generally higher and more developed than the direct or physical measure of the capacity utilization introduced by Färe et al. (1989).

The conventional (or global) measure of capacity utilization is based on the gap between the actual and the (direct or physical) production capacity. When technical inefficiency exists, part of this gap can be bridged by merely eliminating such inefficiency. This is, however, an improvement in efficiency rather than an increase in the rate of capacity utilization. According to FGK, the capacity utilization is measured by the ratio of the efficient output and the physical production capacity. The following decomposition helps identify the different components of the global measure of the capacity utilization rate (GMCU) as:

$$GMCU = EFF \times DIRCU = EFF \times \left(INDIRCU \times SRBC\right)$$

where EFF measure efficiency. Regarding the notation used above,

$$\frac{y}{y^{***}}=\left(\frac{y}{y^*}\right)\times\left(\frac{y^*}{y^{***}}\right)=\left(\frac{y}{y^*}\right)\times\left(\frac{y^*}{y^{**}}\right)\times\left(\frac{y^{**}}{y^{***}}\right) \quad (34)$$

Where y is the actual production, y^* is the efficient production equal to $\varphi^* y$, y^{**} is the indirect production capacity equal to $\beta^* y$, and y^{***} is the physical production capacity equal to $\varphi^C y$ developed by FGK. When the variable cost constraint is binding (i.e., SRBC factor < 1), the direct measure of capacity utilization will be less than the indirect measure of capacity utilization.

Empirical application to the Tunisian manufacturing sector

In this paper, we measure the capacity utilisation of the Tunisian manufacturing sector for the period 1961-2010. We calculate the direct measurement using the model developed by FGK (1989), as well as the indirect measure proposed by Ray et al. (2005), Ray and Lei (2010) and Somayeh et al. (2012), and developed in this paper for the global manufacturing industry (MI) and its six sectors such as: Agricultural and Food Industries (AFI); Building Materials, Ceramics and Glass (BMCG); Mechanical and Electric Industries (MEI); Chemical Industries (CHI); Textiles, Clothing and Leather (TCL) and Various Manufacturing Industries (VMI).

Data and variables

We use annual time series for the Tunisian manufacturing sector built by TICQS (Tunisian Institute of Competitiveness and Quantitative Studies). We consider a production technology with a single output and three inputs. The output is measured by a quantity of the gross production. The inputs are labor, capital and energy. All 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. In the long run, we suppose that technology exhibits 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, we consider a boundary sequence.

Results and empirical analysis

We compute the measure of direct (DIRCU) and indirect (INDIRCU) capacity utilization, the short run budget constraint (SRBC) factor, the efficiency scores (EFF), and the global measurement of the capacity utilization rate (GMCU) for the Tunisian manufacturing and its six

Table 1. Descriptive analysis of direct and indirect capacity utilization

Designation	DIRCU							INDIRCU						
	MI	AFI	BMCG	MEI	CHI	TCL	VMI	MI	AFI	BMCG	MEI	CHI	TCL	VMI
Minimum	0.616	0.523	0.311	0.345	0.233	0.328	0.174	0,616	0,542	0,361	0,538	0,233	0,804	0,675
Maximum	1.000	1.000	1.000	1.000	1.203	1.000	1.054	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Extended	0.384	0.477	0.689	0.655	0.970	0.672	0.880	0,384	0,458	0,639	0,462	0,767	0,196	0,325
1961-1970	0.964	1.000	1.000	0.647	1.000	0.698	0.254	1,000	1,000	1,000	0,984	1,000	0,941	0,817
1971-1981	0.953	0.992	0.870	0.697	0.857	0.671	0.467	0,990	0,992	0,874	0,903	0,857	0,950	0,787
1982-1990	0.742	0.714	0.455	0.743	0.506	1.000	0.899	0,725	0,738	0,445	0,751	0,354	1,000	0,867
1991-2001	0.656	0.622	0.330	0.581	0.267	1.000	0.784	0,656	0,622	0,382	0,581	0,267	1,000	0,784
2002-2010	0.855	0.569	0.363	0.605	0.384	1.000	0.762	0,855	0,584	0,412	0,605	0,384	1,000	0,767
Average	0.834	0.785	0.621	0.694	0.631	0.861	0.641	0,847	0,792	0,638	0,808	0,612	0,971	0,821
S-D	0.138	0.191	0.286	0.204	0.301	0.231	0.280	0,152	0,184	0,271	0,172	0,293	0,052	0,081

SD : Standard Deviation.

Table 2. Descriptive analysis of efficiency scores and short run budget constraint

Designation	EFF							SRBC						
	MI	AFI	BMCG	MEI	CHI	TCL	VMI	MI	AFI	BMCG	MEI	CHI	TCL	VMI
Minimum	0.348	1.000	0.146	0.147	0.090	0.546	0.583	0.826	0.454	0.785	0.271	1.000	0.391	0.218
Maximum	0.875	1.000	0.951	1.000	1.000	1.000	1.000	1.220	1.000	1.447	1.000	4.145	1.000	1.215
Extended	0.527	0.000	0.806	0.853	0.910	0.454	0.417	0.394	0.546	0.662	0.729	3.145	0.609	0.997
1961-1970	0.496	1.000	0.313	0.270	0.400	0.780	0.950	0.931	0.548	1.000	0.617	1.000	0.731	0.309
1971-1981	0.455	1.000	0.200	0.407	0.169	1.000	0.870	0.959	0.866	0.995	0.774	1.000	0.691	0.608
1982-1990	0.639	1.000	0.422	0.646	0.338	1.000	0.757	1.024	0.965	1.030	0.989	1.524	1.000	1.036
1991-2001	0.836	1.000	0.680	0.752	0.946	1.000	0.932	1.000	1.000	0.865	1.000	1.000	1.000	1.000
2002-2010	0.818	1.000	0.730	0.814	1.000	1.000	1.000	1.000	0.974	0.882	1.000	1.000	1.000	0.994
Average	0.645	1.000	0.514	0.616	0.611	0.956	0.922	0.982	0.869	0.959	0.872	1.063	0.878	0.778
S-D	0.174	0.000	0.268	0.265	0.369	0.111	0.112	0.062	0.186	0.094	0.237	0.445	0.220	0.324

Table 3. Descriptive analysis of the global measure of capacity utilization

Designation	GMCU						
	MI	AFI	BMCG	MEI	CHI	TCL	VMI
Minimum	0.325	0.523	0.141	0.058	0.080	0.276	0.161
Maximum	0.751	1.000	0.578	1.000	0.786	1.000	1.000
Extended	0.427	0.477	0.436	0.942	0.706	0.724	0.839
1961-1970	0.482	1.000	0.313	0.164	0.400	0.529	0.241
1971-1981	0.435	0.992	0.166	0.294	0.139	0.671	0.385
1982-1990	0.472	0.714	0.191	0.480	0.161	1.000	0.677
1991-2001	0.548	0.622	0.224	0.435	0.254	1.000	0.730
2002-2010	0.697	0.569	0.265	0.493	0.384	1.000	0.762
Average	0.523	0.785	0.259	0.438	0.309	0.827	0.585
S-D	0.116	0.191	0.096	0.247	0.161	0.249	0.261

corresponding sectors. These results are presented in Tables 1 to 3. Based on the evolution of the industrial production index (see Figure 4), we divided the study period into sub-periods representing global expansions

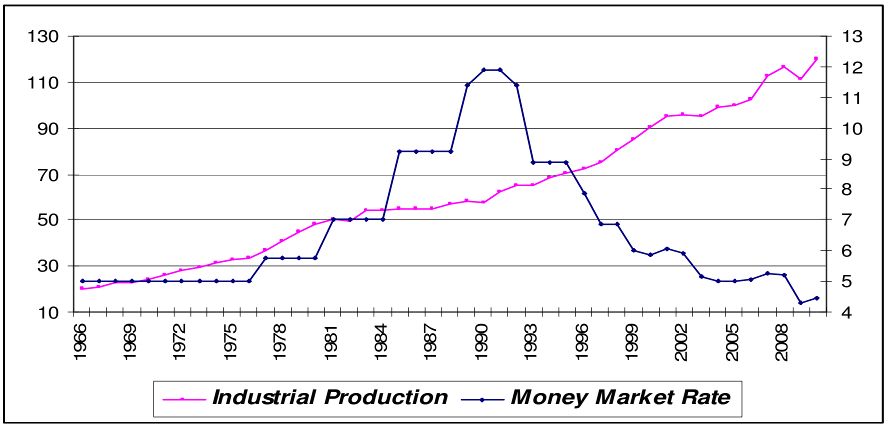

Figure 4. Evolution of industrial production index and money market rate Source IMF.

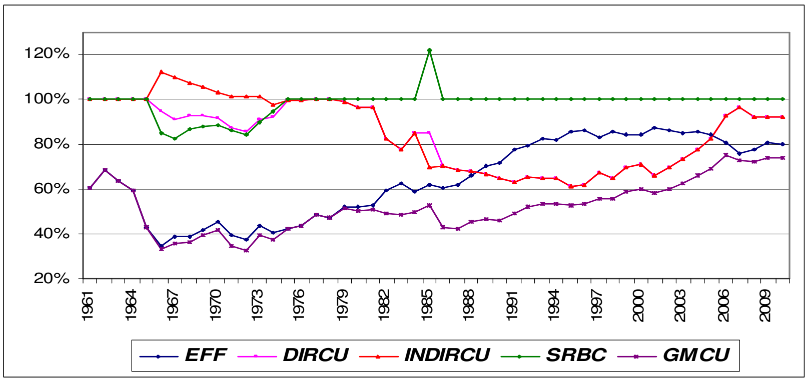

Figure 5. Evolution of different efficiency scores

and contractions of the business cycle in the global economy founded on the different peaks and troughs. Sub-periods 1961-1970, 1982-1990 and 2001-2010 are characterized by strong contractions of the economy, in particular we can see a negative growth recorded in 1982 and 2009. However, the sub-periods 1971-1981 and 1991-2001 experienced good expansions.

For the global manufacturing sector, except for the sub-period 1982-1990, the indirect measure of capacity utilization is higher than the direct one, which means that the variable cost constraint is imposed. Despite a downward trend over years, the direct measurement showed ups and downs compatible with phases of expansion and contraction of the economy in general (see Figure **5**). As explained in Section 2 above, the direct measurement of capacity utilization is, by definition, lower than or equal to the indirect measurement. The indirect measurement of capacity utilization was close to the unit (86%) and from 1987, it was almost equal to the direct measurement. This implies that, in general, firms could not have produced any higher output by mere reallocation between the variable inputs within the overall budget constraint. However, the factor of short-run budget constraint is considerably closer to the unit with the exception of 1985, which was a period of crisis, when the constraint exceeded value one (1.22). This indicates that the budget constraint has been the binding throughout the sampling period. In other words, firms could increase their expenditure (variable cost) to the optimal level that could increase production.

When we focus on disaggregated industries, we find that there is a considerable variation in the capacity utilization rates across the six sectors. In addition, depending on the measure of capacity utilization used, the performance of each sector varies. We find that the direct measurement of capacity utilization is always less than or equal to the indirect measurement in each sub-period for the majority of the sectors. It is sometimes

Table 4. Capacity utilization rates between industries (Global Manufacturing used as a reference)

Designation	DIRCU Sign						INDIRCU Sign					
	AFI	BMCG	MEI	CHI	TCL	VMI	AFI	BMCG	MEI	CHI	TCL	VMI
1961-1970	+	+	+	+	+	+	+	+	+	+	+	+
1971-1981	+	+	+	+	+	+	+	+	+	+	+	+
1982-1990	+	-	+	-	+	+	+	-	+	-	+	+
1991-2001	+	-	-	-	+	+	+	-	-	-	+	+
2002-2010	-	-	-	-	+	+	-	-	-	-	+	+
Global	**+**	**+**	**+**	**-**	**+**	**+**	**+**	**+**	**+**	**-**	**+**	**+**

surprising to see indirect measurements greater than 1 as in the case of the Agricultural and Food Industry (AFI). The only occasion where the direct measurement exceeded the indirect measure was the year 1985, which was characterized by a hard budget constraint higher than the unity in all the sectors without exception. In fact, this period was the real start of the financial crisis in Tunisia. Consequently, the economic context became less favourable, especially in 1985-1986, when several negative factors combined (lower oil prices and drought). Thus, the State pursued a very important policy of public investment, and therefore was forced to borrow heavily, including from commercial banks (Morrison and Talbi, 1996).

The application of the structural adjustment of 1987-88 helped prevent a financial crisis and changed the economic policy. The purpose of this plan is to completely liberate the economy through the liberalization of most prices, parapublic firms, financial sectors and imports. Certainly, the government continues to play an important economic role because of the weight of the parapublic sector in infrastructure, industry and banking.

In general, the indirect measurement of the capacity utilization is higher than 85%. In special cases, for example in Textiles, Clothing and Leather (TCL), the rate exceeded 97.5%. This implies that in these cases, an increase by 10% or more in production has been possible due to the substitution of inputs.

At a global scale, the various measures of capacity utilization (GMCU) are about 52%. According to figure 5, there are two different major phases. In the first one (1962-1966), we observed a sharp drop to 32.5%. In the second phase (from 1967), we recorded a slow growth peaking at 75.1% in 2006. This shows the significant under-utilization of the production factors in the manufacturing sector in Tunisia. In addition, it is shown that the economy is represented by an inefficient technology policy leading to non-constant returns to scale throughout the study period 1961-2010. This industrial inefficiency proven by this performance indicator "CU" is logically proportional to the available resources and the economic policy adopted by the country.

Next, we investigate whether some sectors within our selected group of industries systematically had higher or lower capacity utilization depending on the various measures, as compared to the global manufacturing. Table 4 presents the results of this analysis.

For a given industry or sub-period, a "+" sign corresponds to a measure of capacity utilization in the sector higher than that of the global manufacturing. Besides, a "-" sign means that the capacity utilization rate for that sector is less than that of the global manufacturing. The results are reported for two different measures. For most of the sectors, we predominantly see a "+" sign which means that these sectors had, in general, higher capacity utilization compared to the global manufacturing industry. However, the weak negative signs show the strong under-utilization (or very low) compared to the global index.

By comparing most industries, we find that for all the sub-periods, the capacity utilization in the textile industry is very significant and higher than the one of the manufacturing industry. This high capacity utilization in textiles indicated by the two measures is a bit puzzling, given the several structural changes that occurred in this sector during this period. In case of the Building Materials, Ceramics and Glass (BMCG) and Electrical and Mechanical Industries (EMI), as well as in the Chemical Industries (CHI), we can see that through the use of the direct measurement, the capacity utilization was very low compared to that of the aggregate manufacturing sector and in most sub-periods. The same findings were proven by the indirect measurement.

The convergence of results based on both measures indicates that the short-run budget constraint in these sectors has been highly restrictive. However, during the boom period, 1991-2001, these sectors experienced a lower rate of capacity utilization compared to the global manufacturing sector, which explained both the direct and indirect measures. This is hardly a surprise, given that the boom of the 1990s was led by the high-tech sectors (Agriculture and Food Industry). During the expansion of 1971-1981, and through the use of the direct and indirect measurement, all the sectors recorded

Table 5. Differences between DIRCU and INDIRCU and between industries and periods

Designation	Differences						
	MI	AFI	BMCG	MEI	CHI	TCL	VMI
1961-1970	0.074	0.858	0.000	0.431	0.000	0.243	0.563
1971-1981	0.041	0.184	0.004	0.217	0.000	0.299	0.320
1982-1990	-0.017	0.024	-0.010	0.007	-0.152	0.000	-0.031
1991-2001	0.000	0.000	0.052	0.000	0.000	0.000	0.000
2002-2010	0.000	0.015	0.049	0.000	0.000	0.000	0.005
Global	0.021	0.219	0.017	0.135	-0.018	0.114	0.181

Table 6. Correlations between SRBC and MMR

	MI	AFI	BMCG	MEI	CHI	TCL	VMI
MMR	0.332	0.534	-0.323	0.365	0.185	0.354	0.576

a higher capacity utilization than the global industry.

While the SRBC factor does not reveal the divergence between the two measures of direct and indirect capacity utilization, it may be intuitive to examine the difference between the two measures for each industry and for each sub-period. Table 5 shows the difference between the two measures. This difference is not uniform across industries. It is relatively more important for AFI, MEI, TCL and VMI, while it is relatively lower for BMCG and CHI. In fact, in CHI industry, the direct rates exceed the indirect ones. Greater divergence between both measures suggests that the expenditure constraint is more binding.

Next, we assess the effect of the budget constraints across the sub-periods. We assume that the underlying hypothesis is the fact that the impact of the budget constraint will be more severe when the interest rates are high. During these periods, and by referring to figure 4, the difference between the direct and indirect measure of capacity utilization, in general, should be more pronounced so that the SRBC factor should fall below one. More precisely, our assumption implies that we should observe a negative correlation between the SRBC factor and the Money Market Rate (MMR) as an indicator of interest rates. Table 6 shows this correlation for the global manufacturing sector as well as for the selected sectors.

The situation is as follows. During the period 1961-1978, the AFI and VMI sectors, which represent the highest deviations, were accompanied by SRBC indices less than the unity, although the interest rate was around 5%. The same situation was observed for the global manufacturing sector and the EMI during 1966-1973. For these sectors, we notice positive correlations between the SRBC and MMR. Moreover, the above hypothesis is verified for the BMCG sector during the 1985-1999 periods where the interest rates reached a higher record only at the order of 11.88% and further the coefficient of correlation is significantly negative in the range of -0.332, which implies that in periods of high interest rates, the budget constraint has a more severe impact.

The eighties, as we know, is the period in which the interest rates reached a high record. In most sectors, however, we find that the correlation between the SRBC factor and the interest rate is positive. Although this goes against our hypothesis, the correlations are low (between 0.18 and 0.5). We do recognize that the money market rate is only a general indicator of interest rates in the economy and cannot accurately capture the precise credit conditions for various industries. Overall, however, the data seem to support our hypothesis. In addition, it is important to note that the correlations between the direct, indirect and global capacity utilization rates are strongly and negatively correlated with the interest rates (See Table 7).

As a final step, we focus on the evolution of the various estimates of the production capacity. Figure 6 shows the evolution of the observed output (y) accompanied by efficient production (y^*), indirect production capacity (y^{**}) and physical production capacity (y^{***}). We observe a strong similarity between the measurements of y^{**} and those of y^{***}. Efficient production is still generally below the other two. Indeed, the production capacity has grown at an average rate substantially faster than the actual production. This period is associated with a substantial increase in the capital cost and therefore gave rise to a

Table 7. Matrix of correlations between indicators of the Manufacturing Industry

	Y	Y*	Y**	Y***	EFF	DIRCU	INDIRCU	SRBC	GMCU	MMR
Y	1									
Y*	0.984	1								
Y**	0.968	0.952	1							
Y***	0.969	0.953	0.999	1						
EFF	0.847	0.764	0.876	0.869	1					
DIRCU	-0.452	-0.392	-0.637	-0.640	-0.657	1				
INDIRCU	-0.536	-0.483	-0.714	-0.702	-0.772	0.933	1			
SRBC	0.370	0.370	0.430	0.386	0.525	-0.199	-0.532	1		
GMCU	0.741	0.694	0.618	0.607	0.753	-0.009	-0.219	0.527	1	
MMR	0.133	0.144	0.337	0.324	0.324	-0.747	-0.757	0.332	-0.192	1

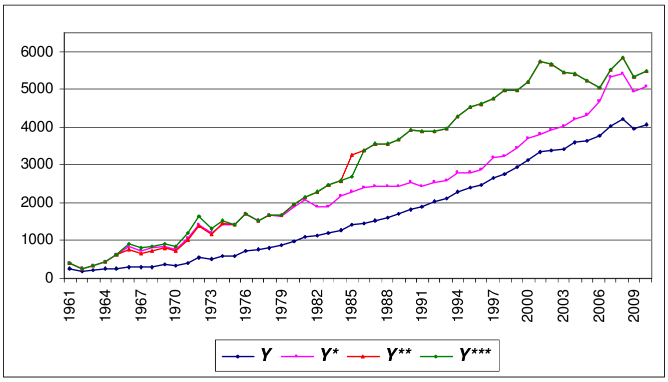

Figure 6. Evolution of different capacity production

decline in the registered level of CU. Conversely, a high rise of CU in 1998 corresponds to a period where the capital user cost decreased substantially, a decrease in the average capital productivity by 47% between 1988 and 1999 (Source: National Institute of Statistics).

Indeed, the capacity utilization rates are less than the unity. Eventually, we can see that the economy, throughout the study period, shows an underutilization of capacity and thus a lack of productive performance regarding the global economy and its sectors. The main reason for these respite periods is uncertain, but we should probably explain this by the poor economic conditions that made it necessary and possible. The under-utilization of capacity could have serious long-run consequences, not only on manufacturing but also on the overall economy. In the medium-run equilibrium, the under-utilization of production capacity reflects a problem of supply rather than of demand. Nevertheless, if the under-utilization of production capacity refers to the theoretical norms of production, it is also and primarily related to imponderables, such as the lack of raw materials supply or equipment due mainly to circumstances sometimes durability.

Conclusions

This document shows the vital role played by the expenditure constraints in determining the capacity utilization rate. We proposed a measure of the production capacity of a firm as the maximum amount produced given a specific quantity of the quasi-fixed input and the overall expenditure constraint for the choice of variable inputs. This approach is based on a restricted version of the indirect production function introduced by Shephard (1970) and complements the direct measure of capacity utilization provided by Färe et al. (1989). We calculated the indirect capacity utilization measure for the Tunisian global manufacturing sector as well as for a group of six manufacturing sectors between 1961 and 2010. Our analysis shows that, despite the general downward trend in the direct measure of capacity utilization in manufacturing over years, it has shown ups and downs compatible with phases of expansions and contractions in the overall economy.

The indirect measure of capacity utilization has been, in general, higher than 85% for the global manufacturing sector; while in some industries, this rate is much higher as it has gone beyond 100%. This implies that firms could not have increased their production very much by a simpler redistribution between the variable inputs within the given budget constraint. The higher CU use is, the less likely to have available opportunities, and the more there is a risk of inflation through demand. Given this situation, the Central Bank expects the capacity utilization to reach its normal level during the year. Nevertheless, when the time at which an increase in the aggregate demand affects the prices rather than the economic activity gets closer, we will have an increasing number of firms gradually coming to full utilization of their production capacity.

In fact, the relationship between the capacity utilization and inflation rate is constrained by uncertainty. In reality, there are several sources of uncertainty, such as the supply shock, the inflation shock and the monetary shock. These different types of shocks have repercussions, in various ways, on inflation and capacity utilization. A demand shock means a random event that positively or negatively affects the economy and it is not entirely predictable. A demand shock has a direct impact on the capacity utilization and an indirect influence on inflation. For our given sample period, the expenditure constraint seems to be more binding for the raw materials through Agricultural and Food Industries, Electrical and Mechanical Industries, and Chemical Industries than for the textile products.

The annual comparison of the expenditure constraint seems to be more restrictive during periods of higher interest rates. More specifically, during the 1980s, when the interest rates reached a high record the expenditure constraint was the most binding, especially for the Building Materials, Ceramics and Glass. During the 1990s expansion, the Food and Agricultural Industries, Various Manufacturing Industries as well as the Textiles, Clothing and Leather showed higher rates of utilization compared to the total manufacturing sector. The very high rate of capacity utilization in the textile industry over the entire sample period, as indicated by both measures, is somewhat puzzling. Our study shows preliminary evidence that the expenditure constraint plays an important role in capacity utilization in the Tunisian manufacturing industry.

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