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Abstract

We measure the capacity output of a firm as the maximum amount producible by a firm given a specific quantity of the quasi-fixed input and an overall expenditure constraint for its choice of variable inputs. We compute this indirect capacity utilization measure for the total manufacturing sector in the US as well as for a number of disaggregated industries, for the period 1970-2001. We find considerable variation in capacity utilization rates both across industries and over years within industries. Our results suggest that the expenditure constraint was binding, especially in periods of high interest rates.

Journal of Economic Literature Classification: D24, L6

Keywords: Data envelopment analysis, expenditure constraint, indirect production function

DIRECT AND INDIRECT MEASURES OF CAPACITY UTILIZATION: A NONPARAMETRIC ANALYSIS OF U.S. MANUFACTURING

The capacity output of a firm can be defined in alternative ways. As a physical upper limit, it measures the maximum quantity of output that a firm can produce from a given bundle of quasi-fixed inputs *even when other (variable) inputs are available without any restriction*. This definition, due to Johansen (1968), is intuitively quite appealing. After all, even when labor, material, and energy are available in unlimited quantities, a firm can produce only a finite quantity of output from its plant and equipment of any given size. The actual output produced must be less than or equal to this capacity output. The rate of capacity utilization, then, is merely the ratio of its actual output and the capacity output level. The capacity utilization in any given context may depend upon a variety of factors. Less than 100% capacity utilization may, for example, be due either to insufficient demand faced by the firm inducing it to restrict production to a level below capacity or due to shortage of some critical input (e.g., energy) holding back production even when there is sufficient demand for the product. A different, and economically more meaningful, definition of the capacity output due to Cassels (1937) is the level of production where the firm's long run average cost curve reaches a minimum. Because we consider the long run average cost, no input is held fixed. For a firm with the typical U-shaped average cost curve, at this capacity level of output, economies of scale have been exhausted but diseconomies have not yet set in. The physical limit defines the capacity of one or more quasi-fixed input. On the other hand, the economic measure pertains to capacity utilization of *all inputs*[1].

[1] See footnote 5 in Klein's paper.

Klein (1960) argued that the long run average cost curve may not have a minimum and proposed the output level where the short run average cost curve is tangent to the long run average cost curve as an alternative measure of the capacity output. This is also the approach adopted by Berndt and Morrison (1981). If the technology exhibits constant returns to scale, the long run average cost curve is horizontal and the capacity level of output is not defined. In this case, however, at the minimum point the short run average cost curve is tangent to the long run average cost curve. This helps to determine the economic capacity output level in the short run and yields a measure of the rate of capacity utilization of the fixed input.

One practical problem with this measure is that the short run total cost at this level of output may exceed the firm's short run budget. In neoclassical economics, a firm, unlike a consumer, does not face a budget constraint. It is postulated that it can choose any feasible input-output combination so long as the output generates enough revenues to cover the expenditure on variable inputs in the short run. This, however, is a rather inaccurate description of the real situation faced by a typical firm. There are various reasons why a firm would like to stay within a budgetary limit in the short run. Given that equity and credit are the two principal sources of fund for a firm and also that additional equity is difficult to raise in the capital market in the short run, borrowing remains the only effective way to finance additional expenses. But this could adversely affect the firm in various ways. First, a higher debt-equity ratio could cause the market to perceive the firm as more risky which in turn would adversely affect its valuation. Second, borrowing on short notice is more likely to be at unfavorable interest rates. A quasi-fixed input is held constant in the short run due to high adjustment costs. In a comparable manner, the firm would keep its total operating expenses within a budgetary limit and avoid excessive cost of credit and adverse market reaction.

The idea of expenditure constraints and their effect on production decisions is not altogether new. Shephard (1953, 1970, 1974) provided a detailed treatment on indirect production theory. The concept of the cost indirect production technology was introduced into the mainstream literature by Ferguson (1969). In the context of U.S. agriculture, Lee and Chambers (1986) empirically test for the effect of the expenditure-constraint on profit maximization of farms. Their results reject the hypothesis of unconstrained profit maximization whereas expenditure-constrained profit maximization cannot be rejected. In a subsequent study, Färe, Grosskopf, and Lee (1990) develop a nonparametric approach (using Data Envelopment Analysis) to expenditure-constrained profit maximization and apply it to data on California rice farms. To our knowledge, however, expenditure constraints have not been incorporated in the measurement of capacity utilization. Further, expenditure constraints have not been integrated even into the analysis of productivity and efficiency in the context of manufacturing.

In this paper we offer a measure of short run capacity output and the associated rate of capacity utilization based on a restricted version of Shephard's (1970) indirect production function. Specifically, we define the capacity output as the maximum quantity producible by the firm given a specific amount of the quasi-fixed input and an overall budget constraint for its choice of variable inputs. Here the firm is permitted to use any variable input bundle *within an overall constraint on expenditure.* In effect, it is a restricted version of the Johansen concept of physical capacity. At the same time, it takes explicit account of relative prices of the variable inputs. Färe, Grosskopf, and

Kokkelenberg (FGK) (1989) provide a nonparametric model using Data Envelopment Analysis (DEA) for measuring the physical capacity output and the associated rate of capacity utilization in the presence of fixed inputs. The present study extends this line of the nonparametric literature by modeling the (unrestricted and restricted) indirect production function(s) and deriving a measure of capacity utilization using DEA. We use annual time series data on aggregate output as well as quantity and price indexes of inputs constructed by the US Bureau of Labor Statistics (BLS) to compute capacity utilization measures in total manufacturing as well as in a number of industries within manufacturing for the period 1970-2001.Our empirical analysis shows considerable variation in capacity utilization rates both across industries and over years within industries. For our given sample period the expenditure constraint seems to be more binding for the primary metals, fabricated metals, electrical and electronic equipment and industrial and commercial machinery sectors than for textile products and petroleum refining. Comparing across years the expenditure constraint seems to be more binding during periods of higher interest rates. Specifically, during the early 1980s when interest rates reached a record high the expenditure constraint was the most binding. During the 1990s expansion the electrical and electronics equipment, industrial and commercial machinery, as well as the textile products sectors show higher rates of utilization as compared to the aggregate manufacturing sector.

The paper unfolds as follows. In section 2 we provide the theoretical background explaining the conceptual issues and describing the nonparametric DEA methodology. Section 3 presents the findings from the empirical analysis and interprets the results. Section 4 is the conclusion.

2 The Theoretical Background:

2.1 Conceptual Issues:

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

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

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

$$f(x) = \max y : (x, y) \in T. \tag{2}$$

If we assume that inputs are freely disposable, then

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

If we assume that outputs are freely disposable, then

$$(x, y) \in T \text{ and } y' \leqslant y \text{ together imply that } (x, y') \in T. \tag{4}$$

Then the maximum output producible from any specific input bundle x^0 is

$$y_0^* = f(x^0) = \max y : x \leq x^0, (x^0, y) \in T. \tag{5}$$

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

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

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

$$y^C(K^0) = \max y : (v, K, y) \in T, K \le K^0, v \ge 0. \tag{7}$$

The *rate of capacity utilization* is

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

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

Now 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 input bundle actually observed is

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

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

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

Thus,

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

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

$$h(w, VC^0, K^0) = g(w, VC^0 | K^0) = f(v, K): w'v \le VC^0; K \le K^0. \tag{12}$$

Here $VC^0 = C^0 - r'K^0$. Note that $r'K^0$ is the fixed cost and even though the firm may choose to utilize less than the total available quantity of the fixed input, that does not release 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, input prices w and actual variable cost VC^0 is

$$\psi(w, VC^0, K^0) = \frac{f(v^0, K^0)}{h(w, VC^0, K^0)}. \tag{13}$$

[Figure 1 about here]

Figures 1, 2a, and 2b graphically illustrate the different capacity utilization concepts described above. 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 not lead to a higher level of output. It remains constant at $y_0^{***} = f(L_0^*, K^0)$.

Thus, the efficient output is

$$y_0^* = \min\{f(L, K^0); y_0^{***}\}.$$

Hence, y_0^{***} is the capacity output 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 the point H once L has increased to L_1^* and

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

where

$$y_1^{***} = f(L_1^*, K^1)$$

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

$$\tau_0 = \frac{y_0}{y_0^*} = \frac{AL_0}{BL_0}$$

whereas the direct measure of capacity utilization is

$$DIRCU_0 = \frac{y_0^*}{y_0^{***}} = \frac{BL_0}{CL_0}.$$

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

$$\tau_1 = \frac{y_1}{y_1^*} = \frac{DL_1}{EL_1}$$

and the direct measure of capacity utilization is

$$DIRCU_1 = \frac{y_1^*}{y_1^{***}} = \frac{EL_1}{FL_1}.$$

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

[Figure 2a about here]

Figure 2a depicts the variable cost curves corresponding to the quasi-fixed input levels K^0 and K^1 for the single output case. The point A in the diagram shows the efficient output producible from some variable input bundle v_0 actually used by a firm that uses quasi-fixed input K^0. The corresponding variable cost is E^0. The variable input bundle actually used is shown by the point *a* in Figure 2b where the axes measure quantities of the variable inputs v^1 and v^2. Note that it lies on the isoquant labeled $y_0^*|K^0$ as well as on the variable cost line VC^0. However, it is not on the highest isoquant attainable on the VC^0 line[2]. If the firm reallocates its expenditure appropriately and moves to the point *b* on the same line VC^0, it can increase its output to y_0^{**}. This is the maximum output feasible from the quasi-fixed input K^0 without increasing the variable cost. In Figure 2a, the corresponding point B on the variable cost curve $VC(y, K^0)$ shows the combination (y_0^{**}, E^0). The indirect capacity utilization rate (*INDCU*) for output y_0 produced from input bundle (L_0, K^0) is

$$INDCU_0 = \frac{Oy_0^*}{Oy_0^{**}} = \frac{E^0A}{E^0B}.$$

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

$$INDCU_1 = \frac{Oy_1^*}{Oy_1^{**}} = \frac{E^1J}{E^1F}$$

In Figure 2b comparison of the points *a* and *b* leads to a measure of the indirect capacity utilization rate. If reallocation of funds between different variable inputs can lead to a significant increase in output, this indirect capacity utilization rate will be low.

[Figure 2b about here]

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[2] Note that VC^0 in figure 2b is equal to E^0 from figure 2a.

Finally, the direct capacity output y_0^{***} is shown by the vertical line through *C* in Figure 2a and by the isoquant $y_0^{***}|K^0$ in Figure 2b. As is apparent from figure 2a, 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

$$SRBC_0 = \frac{Oy_0^{**}}{Oy_0^{***}} = \frac{E^0B}{E^0C}.$$

The distance *CD* measures the shortfall in expenditure on variable inputs while *BC* is a measure of the resulting under-utilization of capacity. The relation 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 less. In that case the short run budget constraint (*SRBC*) factor will be closer to unity. The opposite will be true when marginal cost is lower. We now describe the nonparametric methodology employed in this paper to compute the direct and indirect measures of the capacity output.

2.2 The Nonparametric Methodology:

Suppose that $(x^j) = (v^j, K^j)$ is the observed bundle of variable and fixed inputs and y^j is the output bundle of firm *j* ($j = 1,2,\ldots, N$) 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

$$S = \{(v, K, y) : \sum_{j=1}^{N} \lambda_j v^j \leqslant v; \sum_{j=1}^{N} \lambda_j K^j \leqslant K;$$
$$\sum_{j=1}^{N} \lambda_j y^j \geqslant y; \sum_{j=1}^{N} \lambda_j = 1; \lambda_j \geqslant 0; (j = 1,2,..., N).\} \quad (14)$$

Following Charnes, Cooper, and Rhodes (CCR) (1978) for the input-output bundle

(v^0, K^0, y^0), we have $y_0^* = \varphi^* y^0$, where

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

s.t.

$$\sum_{j=1}^{N} \lambda_j v^j \leqslant v^0;$$
$$\sum_{j=1}^{N} \lambda_j K^j \leqslant K^0;$$
$$\sum_{j=1}^{N} \lambda_j y^j \geqslant \varphi y^0; \quad (15)$$
$$\lambda_{\mathrm{j}} \geqslant 0; (j = 1,2,..., N).$$

Further, as shown by Färe, Grosskopf, and Kokkelenberg (1989),

$$y^C(K^0) = \varphi^C y^0$$

where $\varphi^C = \max \varphi$

s.t.

$$\sum_{j=1}^{N} \lambda_j v^j \leqslant v;$$
$$\sum_{j=1}^{N} \lambda_j K^j \leqslant K^0;$$
$$\sum_{j=1}^{N} \lambda_j y^j \geqslant \varphi y^0; \quad (16)$$
$$\lambda_{\mathrm{j}} \geqslant 0; (j = 1,2,..., N).$$

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

For the indirect production function, we solve the following DEA model[3]:

$$\delta^* = \max \delta$$

s.t.

$$\begin{aligned}
&\sum_{j=1}^{N} \lambda_j v^j \leqslant v; \\
&\sum_{j=1}^{N} \lambda_j K^j \leqslant K; \\
&\sum_{j=1}^{N} \lambda_j y^j \geqslant \delta y^0; \\
&w' v + r' K \leqslant C^0; \\
&\lambda_{\mathrm{j}} \geqslant 0; (j = 1,2,\ldots, N).
\end{aligned} \tag{17}$$

The optimal solution to (17) yields the indirect production function,

$$g(w, r, C^0) = \delta^* y^0. \tag{18}$$

Finally, our proposed restricted indirect production function introduced in (12) above is

$$h(w, VC^0, K^0) = \beta^* y^0, \tag{19}$$

where

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

s.t.

[3] Note that in model (17) C^0 is the budgeted Total Cost.

$$
\begin{aligned}
&\sum_{j=1}^{N} \lambda_j v^j \leqslant v; \\
&\sum_{j=1}^{N} \lambda_j K^j \leqslant K^0; \\
&\sum_{j=1}^{N} \lambda_j y^j \geqslant \beta y^0; \\
&w'v \leqslant VC^0; \text{ where } VC^0 = C^0 - r'K^0 \\
&\lambda_j \geqslant 0; (j = 1,2,...,N).
\end{aligned} \tag{20}
$$

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

$$\varphi^C \geq \beta^* \geq \varphi^*. \tag{21}$$

Thus,

$$\gamma(K^0) = \frac{\varphi^*}{\varphi^C} \leqslant \psi(w, VC^0, K^0) = \frac{\varphi^*}{\beta^*}. \tag{22}$$

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

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

$$OV = EFF \times DIRCU = EFF \times (INDCU \times SRBC)$$

In terms of the notations used above,

$$\frac{y}{y^{***}} = (\frac{y}{y^{*}}) \times (\frac{y^{*}}{y^{***}}) = (\frac{y}{y^{*}}) \times (\frac{y^{*}}{y^{**}} \times \frac{y^{**}}{y^{***}}) \quad (23)$$

where y = actual output, y^{*} = efficient output = $\varphi * y$, y^{**} = indirect capacity output = $\beta * y$, and y^{***} = physical (FGK) capacity output = $\varphi^{C} y$. 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.

3 Application to U.S. Manufacturing:

3.1 A brief review of previous studies:

Capacity utilization is considered to be an important measure of economic performance and indicator of the strength of aggregate demand in the economy. In the U.S., the Federal Open market Committee examines it along with other variables in assessing the tightness of the economy. Several studies have addressed the question of capacity utilization in U.S. manufacturing. In general such studies have followed one of the two following approaches. The first group of studies obtains measures of capacity utilization as derived from an estimated cost function. Berndt and Morrison (1981) propose an economic measure of capacity utilization based on a dynamic cost function model. Treating capital as the single quasi-fixed input in one case and capital and non-production labor as the two quasi-fixed inputs in the other case the capacity utilization measure for each year between 1958 and 1977 is greater than 1 for U.S. manufacturing in both cases. In a more recent study, Kim (1999) develops and estimates a model of economic capacity utilization and its determinants while treating output as endogenous. The model is applied to total U.S. manufacturing for the period 1948-1981. The measured capacity utilization is greater than 1 in almost every year. The empirical results from that study show that while higher materials and capital prices leads to lower capital utilization, higher energy price increases capacity utilization. While the above studies focus on U.S. manufacturing at the national level, the study by Garofalo and Malhotra (1997) focuses on regional measures of capacity utilization in U.S. manufacturing during the period 1983-1990. They find that faster growing states and states with lower input prices have higher utilization rates whereas states with high capital-output ratio and low proportion of high-technology industries in their manufacturing sector generally have low utilization rates. For the U.S. as a whole the average of the measured capacity utilization over their study period was 79.09 %.

The other group of studies takes the Federal Reserve's measure of capacity utilization and investigates the macroeconomic implications of a high or low utilization rate. Shapiro (1989) investigates the dynamic relationship between lagged capacity utilization rates (as measured by the Federal Reserve) and production, between lagged utilization rates and changes in relative prices, and also between utilization and other macroeconomic variables. His study covers the period 1967-88 and is applied to aggregate manufacturing as well as several disaggregated industries.[4] He finds that relative prices do not rise significantly during states of high capacity utilization. Further his findings do not support the hypothesis that high capacity utilization acts as a barrier to further output expansion. On the other hand using the Fed's capacity utilization measures for the aggregate manufacturing sector for 1967-1995, Corrado and Mattey (1997) find noticeably positive correlation between the capacity utilization rates and the acceleration of consumer prices excluding food and energy. The correlation between manufacturing

[4] These are mining, primary metals, iron and steel, aluminum, paper, motor vehicles, aerospace, petroleum, chemicals, and electrical utilities.

capacity utilization and acceleration of manufactured goods prices is even higher. They find that inflation begins to accelerate particularly when capacity utilization exceeds a threshold of around 82%.

In this paper we measure the capacity utilization in the U.S. manufacturing sector for the period 1970-2001. We compute both the direct measure using the model developed by FGK (1989) as well as the indirect measure as proposed in this paper, for the aggregate manufacturing industry along with several disaggregated 2-digit level sectors within manufacturing – primary metals (SIC 33), fabricated metal products (SIC 34), chemical and allied products (SIC 28), transportation equipment (SIC 37), electrical and electronic equipment (SIC 36), industrial and commercial machinery, and computer equipment (SIC 35), petroleum refining and related industries (SIC 29), and textile mill products (SIC 22).[5]

3.2 Data:

We use annual time series data for the manufacturing sector constructed by the U.S. Bureau of Labor Statistics. The data were available for the years 1949 and 1953 through 2001. We conceptualize a single-output, five-input production technology. Our single output is the quantity index of gross output for the sector. Our five inputs are (i) capital, (ii) labor, (iii) energy, (iv) materials, and (v) services. For the ‘sectoral’ output of the 2-digit level industries the BLS takes the deflated value of production of that sector net of the portion consumed by the same industry. As for the inputs, the BLS measures labor as the hours worked by all persons engaged in the sector. Capital input is defined as the flow of services from physical assets which include equipment, structures, inventories, and

[5] The gross value of production in the total manufacturing sector for the year 2000 in current dollars was $2729.071 billion. Of this, our selected 2-digit level industries together accounted for $2088.38 billion i.e., roughly 77% of manufacturing output in the U.S. (Source: Bureau of Labor Statistics).

land. Energy input is constructed using data on price and quantity of fuels purchased for use as heat or power. Data for the separate energy categories are Törnqvist aggregated to obtain the energy quantity index. Materials input include all commodity inputs exclusive of fuels. The services input represents purchased business services. All inputs are measured by the appropriate quantity indexes with 1996 as the base year.[6] In our analysis we treat capital as the quasi-fixed input and the remaining four as variable inputs. Further, price indexes of individual inputs are used as relevant input prices in the optimization problems.

A basic problem in using time series data is that for each year only one observed input-output bundle is available, so it is not possible to construct contemporaneous frontiers for each year. We circumvent this problem by constructing sequential frontiers. In other words, in evaluating the input-output bundle for any given year we assume that all previously observed input-output bundles are feasible production plans. This amounts to assuming that technical change is non-regressive. Further we assume that the technology exhibits constant returns to scale. This assumption is based on two reasons. First, our input- output bundles for each year comprise the 'total' input-output bundle for all firms in that industry. While the individual firm level input-output combinations are feasible, the 'total' input-output bundle is feasible only if the technology is additive which implies constant returns to scale. Secondly, in its data construction, the BLS assumes that the total cost of production equals the total value of production i.e., assumes product exhaustion. This is consistent only with constant returns to scale.

[6] These definitions are from the Bureau of Labor Statistics. For a detailed description of data construction by the BLS see Gullickson and Harper (1987).

3.3 Empirical Results and Analysis:

We compute the direct measure of capacity utilization (*DIRCU*), the indirect measure of capacity utilization (*INDCU*), as well as the *SRBC* factor for U.S. manufacturing for the period 1970-2001. In Table 1 we report these measures along with the Federal Reserve's (FRB) measure of capacity utilization.[7] In light of the importance of the short run budget constraint we also report the prime rate of interest, which serves as a general indicator of credit conditions in the economy.[8] For the total manufacturing sector these are summarized in Table 1.1. Tables 1.2 through 1.9 summarize similar information for the selected 2-digit level industries. We divide the sample period into sub-periods broadly representing the business cycle expansions and contractions in the overall economy, based on the National Bureau of Economic Research's (NBER) dating of peaks and troughs. While the sub-periods 1974 -1975, and 1981-1982 experienced contractions of the economy, 1970 -1973, 1976 -1980, 1983 -1990, and 1991 -2001 experienced expansions.[9] For the total manufacturing sector, except in the 1970 -1973 and 1974 -1975 sub-periods, the direct measure of capacity utilization has been lower than the FRB measure. Despite a downward trend over years, the direct measure has shown ups and downs consistent with phases of expansion and contraction of the overall

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[7] The Fed's measure of capacity utilization is based on survey evidence. The capacity output is defined as the maximum output producible by each plant in a given industry that is practical and sustainable taking into account a normal downtime as well as sufficient availability of inputs (see Corrado and Mattey, 1997). Of the eight 2-digit industries in our study, the Fed's measure was not available for three industries. They are electrical and electronic equipment, industrial and commercial machinery, and petroleum refining and related industries.

[8] Data on prime rate charged by banks was obtained from the *Economic Report of the President*, 2005, Table B-73.

[9] While the NBER characterizes specific months as peaks or troughs, our data being annual could not be exactly matched with the NBER dates. For example, within the 1991-2001 sub-period, March 1991 was a trough, March 2001 was a peak, and November 2001 was another trough. We consider the overall 1991-2001 as an expansionary period.

economy. As explained in section 2 above, the direct measure of capacity utilization is by definition less than or equal to the indirect measure. The indirect capacity utilization measure has been close to unity except in the 1974 -1975 sub-period. 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. In contrast, the short run budget constraint factor is considerably less than 1, ranging from a low of 0.675 in 1981-1982 to a high of 0.8718 in 1970-1973. This indicates that the budget constraint has been binding over the sample period. In other words had the firms been able to increase their expenditure (variable cost) to the optimal level they could have increased output.

[Table 1 about here]

When we focus on the disaggregated industries we find that within any one sub-period there is considerable variation in capacity utilization across industries. Further, depending on which measure of capacity utilization is used, the performance of each industry varies. We find that the direct measure of capacity utilization is consistently lower than the FRB measure in each sub-period for the primary metals and fabricated metals sectors, whereas it is consistently higher than the FRB measure in each sub-period for textile products. For both chemical products and transportation equipment the direct measure exceeded the FRB measure during the 1970-1973 and 1974-1975 sub-periods but was less than the FRB measure for each of the subsequent sub-periods. In general the indirect measure of capacity utilization has been higher than 0.9. In specific cases, for example: petroleum refining in 1981- 1982, transportation equipment in 1976-1980, primary metals in 1983-1990, and chemicals in 1976-1980, it has been less than 0.9. This implies that in these specific cases, an increase of 10% or more in output would have been possible through input substitution.

[Table 2 about here]

We next investigate whether some sectors within our selected group of industries systematically experienced higher or lower capacity utilization based on the various measures, as compared to total manufacturing. Table 2 reports the results of this analysis. For a given industry and sub-period a '+' sign corresponding to a measure of capacity utilization implies that the utilization rate for that industry is higher than that for total manufacturing. On the other hand a ' – ' sign implies that the capacity utilization rate for that industry is less than that for total manufacturing. The results are reported for the three different measures. For most of the industries we see predominantly ' – ' signs implying that these industries in general experienced lower capacity utilization than the aggregate manufacturing sector. Comparing across industries we find that for all sub-periods the capacity utilization in textiles is very high[10] and higher than that for total manufacturing. This high capacity utilization rate in textiles indicated by all three measures is somewhat puzzling, especially given the multitude of structural changes that have taken place in this sector over this period.[11] In case of electrical and electronics

[10] This can be seen from Table 1.

[11] It may be worthwhile to note in this context that even according to the multifactor productivity index measured and reported by the BLS, the textile industry's performance was superior when compared to aggregate manufacturing during the 1970-2001 period. Based on the BLS Total Factor Productivity (TFP) measures, the average annual growth rate of productivity for textile (manufacturing) corresponding to our sub-periods was 1.875% (1.7%) for 1970-1973; 1.5% (-4.15%) during 1974-1975; 3.86% (0.7%) for 1976-

equipment as well as for the industrial and commercial machinery (which includes computer equipment) sectors we observe that in terms of the direct measure, the capacity utilization in these two sectors was lower than for the aggregate manufacturing sector in each of the sub-periods. In contrast, the indirect measure provides a different picture. The capacity utilization in terms of the indirect measure is in general higher for each of these two sectors as compared to the aggregate manufacturing sector. The divergent results based on the two measures indicate that the short run budget constraint in these two sectors has been substantially binding. During the 1991-2001 expansion, however, both these sectors experienced higher capacity utilization than the aggregate manufacturing sector which is evidenced by both the direct and indirect measures of capacity utilization. This is hardly a surprise, considering that the 1990s boom was led by the high tech sectors. In case of chemical products and transportation equipment the utilization rates were higher than for aggregate manufacturing during the 1970-1973 expansion according to both the direct and indirect measure although not according to the FRB measure.

[Table 3 about here]

While the *SRBC* factor itself reveals the divergence between the direct and indirect measures of capacity utilization, it may be intuitive to also look at the difference between the two measures for each industry and sub-period. Table 3 reports the difference between the two measures. This difference between the direct and the indirect

1980; 3.95% (1.1%) for 1981-1982; 1.625% (1.488%) for 1983-1990; and 1.745% (1.545%) for 1991-2001. A study by Levinsohn and Petropoulos (2001) covering the period 1972-1992 find similar superior performance for the textile industry based on their own measure of TFP. Examining several aspects of that industry they conclude that the US textile industry exhibits the case of 'creative destruction' in the Schumpeterian sense.

measures of capacity utilization also is not uniform across industries. The difference is relatively larger for primary metals, fabricated metals, electrical and electronic equipment and industrial and commercial machinery whereas it is relatively smaller for textile products and petroleum refining. A greater divergence between the two measures suggests that the expenditure constraint is more binding.

[Table 4 about here]

Next we assess the effect of the budget constraint across the sub-periods. Here our underlying hypothesis is that the impact of the budget constraint will be more severe during periods of high interest rates. During these periods the divergence between the direct measure of capacity output and the indirect measure of capacity output should be more pronounced so that the *SRBC* factor should fall further below 1. In other words, our hypothesis implies that we should observe a negative correlation between the *SRBC* factor and the prime rate of interest. Table 4 reports this correlation for total manufacturing as well as for the selected industries. For the total manufacturing sector we see that there is a discernible relationship between the prime rate and the *SRBC* factor. The correlation coefficient of -0.4015 implies that in periods of high interest rates the budget constraint has had a more severe impact. Of the eight individual industries, five show the expected negative correlation. Further, Table 1 reveals that in case of total manufacturing as well as for primary metals, chemical and allied products, transportation equipment, and industrial and commercial machinery the *SRBC* factor is the lowest for the sub-period 1981-1982 i.e., the budget constraint was most binding during this sub-period. For the other four industries too the *SRBC* factor reached a very low value during 1981-82, again highlighting the role of the budget constraint. The early eighties as we know was the period in which interest rates reached a record high. The prime rate charged by banks was 18.87 % in 1981 and 14.86% in 1982 for an average of 16.865%. In case of three sectors, however, we find that the correlation between the *SRBC* factor and the prime rate is positive (see Table 4). While this runs counter to our hypothesis, the correlations are very low: 0.0866 in case of the electrical and electronic equipment sector, 0.193 in case of the industrial and commercial machinery sector, and 0.01095 for textile products sector. We do recognize that the prime rate of interest is only a general indicator of interest rates in the economy and may not exactly capture the precise credit conditions for the individual industries. Overall, however, the data does seem to support our hypothesis.

4 Summary and Conclusions:

This paper recognizes the critical role played by expenditure constraints in the determination of capacity utilization. We offer a measure of capacity output of a firm as the maximum amount producible by the firm, given a specific quantity of the quasi-fixed input and an overall expenditure constraint for its choice of variable inputs. Our approach is based on a restricted version of the indirect production function introduced by Shephard (1970) and complements the direct capacity utilization measure provided by Färe, Grosskopf, and Kokkelenberg (1989). We compute the indirect capacity utilization measures for the total manufacturing sector in the US as well as a group of 2-digit level industries within manufacturing for the period 1970-2001. Our analysis shows that despite the overall downward trend in the direct measure of capacity utilization in total manufacturing over years, it has shown ups and downs consistent with phases of expansions and contractions of the overall economy. The indirect measure of capacity utilization has in general been higher than 0.9 for total manufacturing as well as for our selected individual industries, implying that firms could not have increased their output very much by mere reallocation between the variable inputs within the given budget constraint. For our given sample period the expenditure constraint seems to be more binding for the primary metals, fabricated metals, electrical and electronic equipment and industrial and commercial machinery sectors than for textile products and petroleum refining. Comparing across years the expenditure constraint seems to be more binding during periods of higher interest rates. Specifically, during the early 1980s when interest rates reached a record high the expenditure constraint was the most binding. During the 1990s expansion the electrical and electronics equipment, industrial and commercial machinery, as well as the textile products sectors show higher rates of utilization as compared to the aggregate manufacturing sector. The very high rate of capacity utilization in the textile industry over the entire sample period, as indicated by all three measures, remains somewhat puzzling. Our study finds preliminary evidence that the expenditure constraint plays an important role in the capacity utilization in US manufacturing. A detailed analysis of individual industries within manufacturing would be a logical follow up of this study, which is beyond the scope of this paper.

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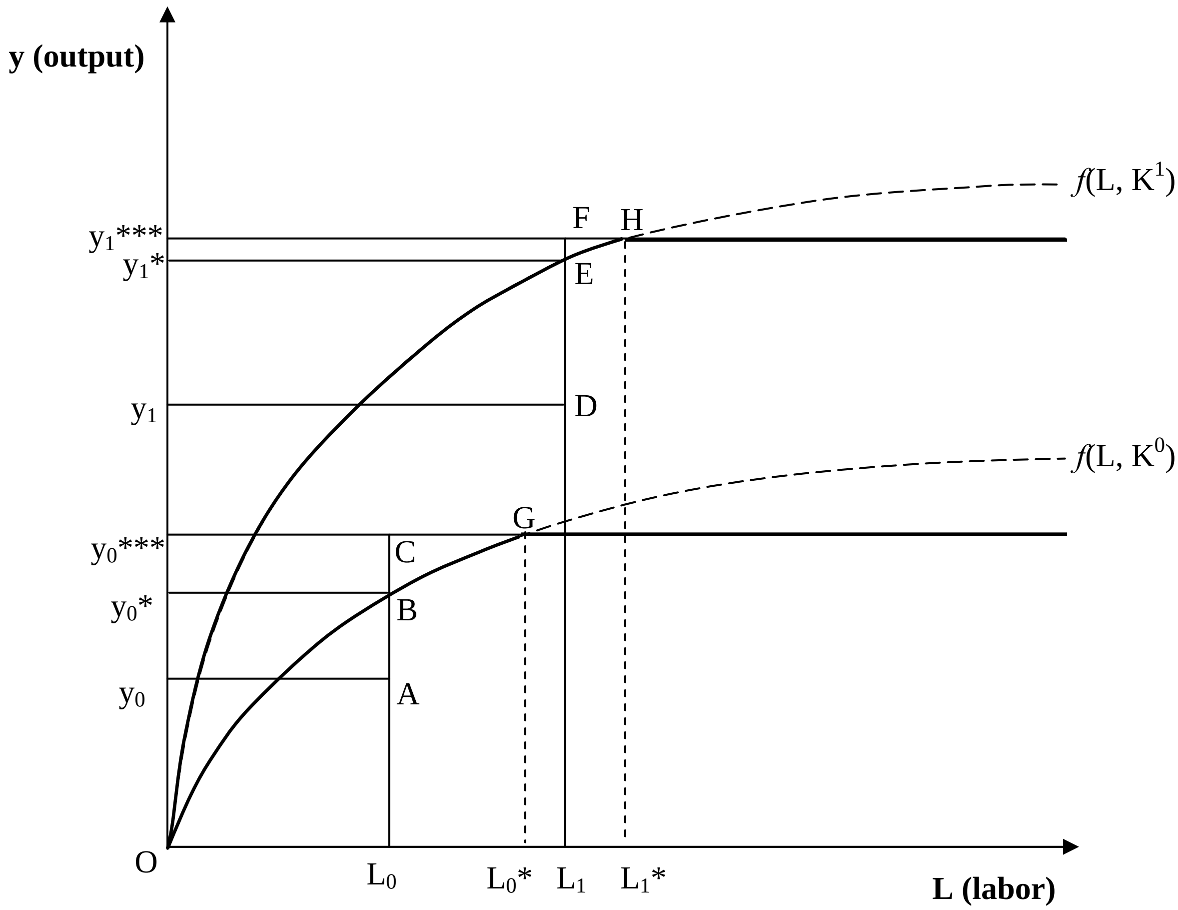

Figure 1: Direct Measure of Capacity Utilization

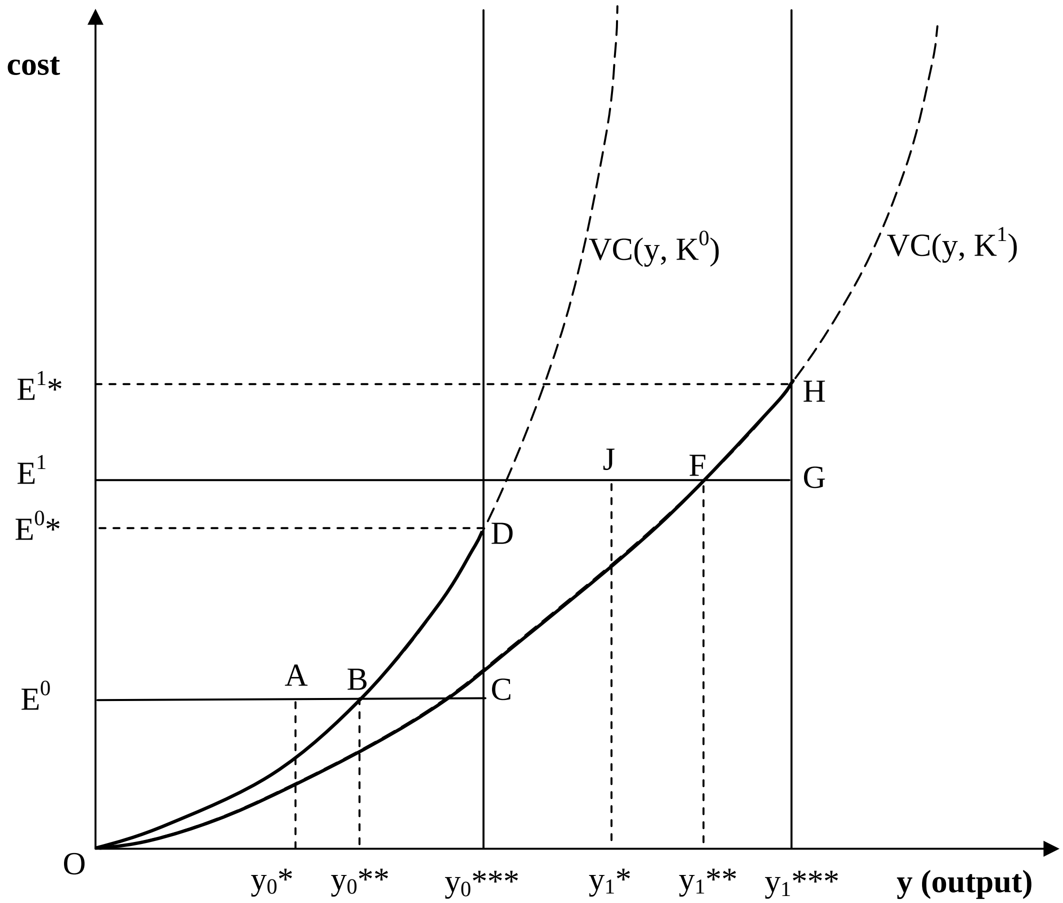

Figure 2a: Indirect Measure of Capacity Utilization

$$INDCU_0 = \frac{Oy_0^*}{Oy_0^{**}} = \frac{E^0 A}{E^0 B}$$

$$SRBC_0 = \frac{Oy_0^{**}}{Oy_0^{***}} = \frac{E^0 B}{E^0 C}$$

$$INDCU_1 = \frac{Oy_1^*}{Oy_1^{**}} = \frac{E^1 J}{E^1 F}$$

$$SRBC_1 = \frac{Oy_1^{**}}{Oy_1^{***}} = \frac{E^1 F}{E^1 G}$$

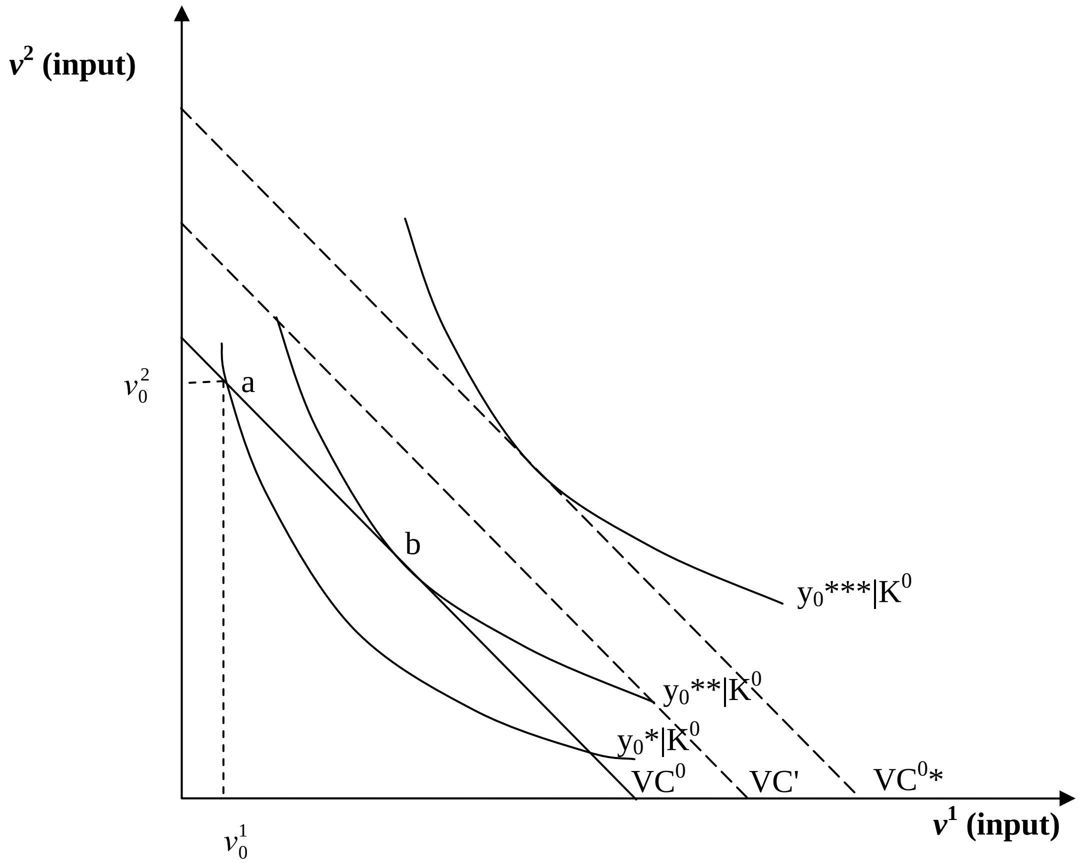

Figure 2b: Interpretation of Indirect Measure of Capacity Utilization

Table 1.1: Total manufacturing

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.8692	0.7926	0.7912	0.6774	0.7267	0.7423
INDCU	0.997	0.9336	0.9839	0.997	0.9939	0.9922
SRBC	0.8718	0.8486	0.804	0.6795	0.7313	0.7481
FRB	0.8193	0.7876	0.8157	0.7426	0.8002	0.8063
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.2: Primary metal industries

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.6445	0.6469	0.5773	0.4584	0.4532	0.5397
INDCU	0.9664	0.9634	0.8966	0.9919	0.8721	0.9702
SRBC	0.6663	0.6717	0.6442	0.52	0.5207	0.5559
FRB	0.8206	0.8474	0.8141	0.6662	0.7574	0.8565
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.3: Fabricated metal products

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.7828	0.677	0.6398	0.5308	0.5522	0.5621
INDCU	0.9399	0.9157	0.9244	0.9313	0.9758	0.9906
SRBC	0.8328	0.7383	0.692	0.5698	0.5661	0.5672
FRB	0.8327	0.79	0.7866	0.6949	0.7456	0.7815
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.4: Chemical and allied products

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.9724	0.8953	0.7739	0.6363	0.705	0.6778
INDCU	1	0.9207	0.8899	0.9403	0.9915	0.9621
SRBC	0.9724	0.9714	0.8704	0.6788	0.7115	0.7054
FRB	0.7843	0.7756	0.7928	0.7224	0.7948	0.7876
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.5: Transportation equipment

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.9724	0.8953	0.7739	0.6363	0.705	0.6778
INDCU	1	0.9207	0.8899	0.9403	0.9915	0.9621
SRBC	1	0.9714	0.8704	0.6788	0.7115	0.7054
FRB	0.7843	0.7756	0.7928	0.7224	0.7948	0.7876
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.6: Electrical and electronic equipment

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.7322	0.6252	0.6642	0.5746	0.561	0.7914
INDCU	0.9964	0.9621	0.9965	1	1	1
SRBC	0.7348	0.6493	0.6664	0.5746	0.561	0.7914
FRB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.7: Industrial and commercial machinery, computer equipment

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.7377	0.6894	0.6795	0.5591	0.6135	0.7542
INDCU	0.9848	0.9829	1	0.9975	1	0.9987
SRBC	0.7487	0.7007	0.6795	0.5604	0.6135	0.7549
FRB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.8: Petroleum refining and related industries

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.9781	0.9054	0.8796	0.6681	0.7246	0.7677
INDCU	1	0.9281	0.9593	0.8866	0.9638	0.985
SRBC	0.9781	0.9754	0.9165	0.7536	0.7513	0.7798
FRB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 1.9: Textile mill products

	1970-73	1974-75	1976-80	1981-82	1983-90	1991-2001
DIRCU	0.9851	0.8645	0.985	0.9402	0.9899	0.9289
INDCU	0.9997	0.9935	1	1	0.9997	0.9985
SRBC	0.9855	0.8703	0.985	0.9402	0.9902	0.9304
FRB	0.8416	0.7432	0.8595	0.7733	0.8552	0.8416
Prime Rate	6.7275	9.335	10.134	16.865	9.9375	7.8082

Table 2: Capacity Utilization across industries (total manufacturing used as benchmark)

		70-73	74-75	76-80	81-82	83-90	91-01
Primary metals	***DIRCU***	-	-	-	-	-	-
	INDCU	-	+	-	-	-	-
	FRB	+	+	-	-	-	+
Fabricated metals	***DIRCU***	-	-	-	-	-	-
	INDCU	-	-	-	-	-	-
	FRB	+	+	-	-	-	-
Chemical products	***DIRCU***	+	+	-	-	-	-
	INDCU	+	-	-	-	-	-
	FRB	-	-	-	-	-	-
Transportation equipment	***DIRCU***	+	+	-	-	-	-
	INDCU	+	-	-	-	-	-
	FRB	-	-	-	-	-	-
Electrical and electronic equipment	***DIRCU***	-	-	-	-	-	+
	INDCU	-	+	+	+	+	+
	FRB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Industrial and commercial machinery	***DIRCU***	-	-	-	-	-	+
	INDCU	-	+	+	+	+	+
	FRB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Petroleum refining	***DIRCU***	+	+	+	-	-	+
	INDCU	+	-	-	-	-	-
	FRB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Textile products	***DIRCU***	+	+	+	+	+	+
	INDCU	+	+	+	+	+	+
	FRB	+	-	+	+	+	+

Table 3: Difference between *DIRCU* and *INDCU* measures

Total manufacturing	0.228
Primary metals	0.388
Fabricated metals	0.357
Chemical products	0.212
Transportation equipment	0.224
Electrical and electronic equipment	0.314
Industrial and commercial machinery	0.307
Petroleum refining	0.165
Textile products	0.042

Table 4: Correlation between *SRBC* and Prime rate

	Correlation coefficient
Total manufacturing	-0.401455548
Primary metals	-0.057120867
Fabricated metals	-0.198567324
Chemical products	-0.272840516
Transportation equipment	-0.512281655
Electrical and electronic equipment	0.086603629
Industrial and commercial machinery	0.193006305
Petroleum refining	-0.758470931
Textile products	0.010954877