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THE MEASUREMENT AND SOURCES OF TECHNICAL EFFICIENCY IN THE MANUFACTURING INDUSTRY: A CASE STUDY FOR BRAZIL (*)

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1 — Introduction

This paper examines the relative efficiency of industrial establishments operating in the state of Minas Gerais, and offers empirical evidence whether inefficient firms share some common set of characteristics. To accomplish this we make use of a micro data file sample for 281 individual manufacturing industries compiled for 1982 from the corporate reports and balance sheet informations. Studies based on micro data may have a comparative advantage over that based on aggregate data insofar as most of the decision-making on the type of technology to adopt and its operation are taken at the micro level.

In view of the serious regional imbalances which prevail in Brazil, it would be interesting to analyse the perfomance of the manufacturing industry in each region and according to their different characteristics. Minas Gerais was elected as a case study because, among other things, this state underwent significant economic expansion, with its economy registering growth rates higher than those achieved by the country as a whole. In an effort to develop, the state's government has directly and indirectly promoted industrial growth by means of an institutional and promotional apparatus developed during the 1960s and early 1970s. Consequently, the manufacturing activity moved towards a position of being the leading growth sector of the state's economy ([1]).

In the subsequent sections of this paper we shall review the method used and propose an operational measure of inter-firm differences in efficiency; carry out a number of tests of the proposed measure; and draw certain conclusins regarding the relative efficiency of industrial establishments operating in Minas Gerais.

2 — The measurement and interpretation of efficiency frontiers

Most of the attempts to evaluate efficiency level amongst firms utilize production functions in their measurement. The more traditional approach deals

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([1]) Issues related to regional disparities in Brazil and structural chage in the state's economy can be seen in Alves (1986, chapters 2 and 3).

with «average» production functions for the industry, i. e., the production function of the «average» (representative) firm or region.

In this paper we will deal with a slightly different concept of production function, namely the «frontier function». That is, from the viewpoint of an individual firm the best that can be achieved is to be on the boundary or frontier of the best practice technique at the correct set of relative factor prices. The position of other firms can than be compared with such a point on the best practice boundary and this provides on standard against which efficiency differences can be compared. Excluding price or allocative efficiency effects, simply being on the frontier is the relevant criterion for maximum success in technical terms.

The pioneer work in this field was that of M. Farrel (1957), who suggested the concept of «frontier function» in measuring efficiency differentials between firms. Although work has been progressing on this field for nearly three decades, only recently has it attracted widespread attention [Meller (1976), Tyler (1979), Aigner and Schmidt (1980), Page, Jr. (1984), and Todd (1985)].

Farrel developed an ingenious method of measuring differences in efficiency among the firms of an industry. As Farrel points out, the purpose of this approach is to compare the performance of actual firms with the best practices observed in reality, instead of taking ideal combinations of inputs as a point of reference.

Figures 1 and 2 below illustrate the Farrel approach. Assuming an input-input space per unit of output, the realitive efficiency of firms may be drawn in a two-dimensional diagram like that of figure 1, i. e., the usual isoquant diagram. Assume that we are interested in analysing the level of efficiency of firm *P*. To measure it, it is necessary to have an a priori knowledge of the conditions faced by the most efficient firm. Assume that *SS'* represents the various combinations of the two factors which a perfectly efficient firm might use to produce a unit of output. Given the actual combination of inputs in firm *P*, this may be compared with point *Q*, which shows the same factor proportions as *P*, and which lies on the isoquant of the efficient firm. The ratio *OQ/OP* then defines what Farrel calls «technical efficiency», which is a measure that relates to an inappropriate choice of production function among all those actually in use by the firms in the industry.

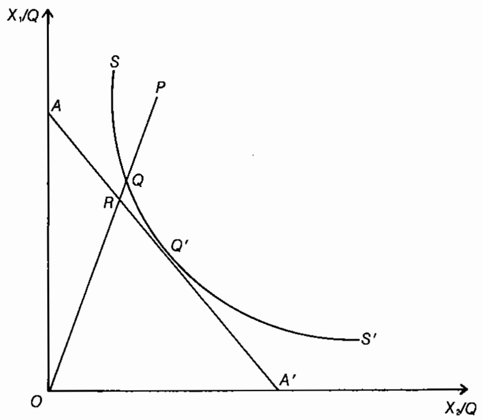
Let *AA'* be the isocost line given a relative price between X_1 and X_2. The efficient firm will produce at point *Q'* instead of at point *Q*, because at this point its cost will be lower. Therefore, with a different combination of inputs, firm *P* could produce at a cost equal to *R* if the right techniques and factor prices had been adequately chosen. The ratio *OR/OQ* measures what Farrel called «price efficiency» and as such it refers to the proper (or improper) choice of input combinations. The «overall efficiency» is the product of both «price» and «technical efficiency», i. e., $OR/OP = OR/OQ \bullet OQ/OP$.

In view of the absence of factor price information (2) the discussion in this paper will center on technical efficiency, and the central question is then how to estimate the unit isoquant of the most efficient firm? Farrel estimates it by fitting an envelope of the type shown in figure 2 to the scatter of pints in the input plane. The author assumes that the «efficient» isoquant is convex to the origin and that if two pints are attainable in practice, so is any point representing a weighted average of then. Therefore, this hypothetical function is constructed as a weighted average of the more efficient firms, the weights being chosen so as to give the desired factor proportions. Hence, each point in figure 2 represents the observed unit factor requirements of a firm. All points such as *B, C, D,* and *E* have maximum efficiency insofar as the combination X_1 and X_2 is such that reducing the amount of either requires an increase in the amount of the other input.

Summing up it could be said that Farrell's approach has several advantages: insofar as it is functional form free it does not introduce a bias into the technical efficiency measure which is normally present when a functional forms is specified; it can handle firms using heterogeneous technologies and techniques; and it is a useful and simple tool for measuring the relative technical efficiency of different techniques.

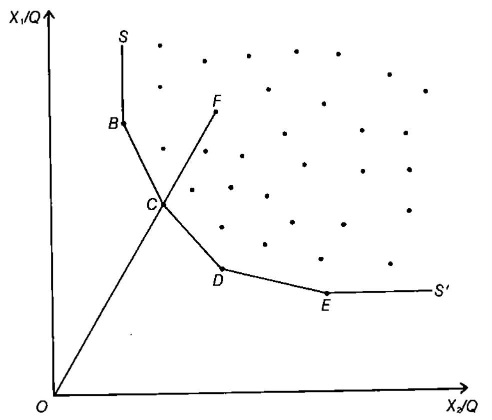
However, some of the method's limitations should be noted. The frontier is computed from a supporting subset of observations from the sample and is therefore sensitive to extreme observations and measurement error; underutilization of capacity may also introduce biases in estimating the real frontier; the number of observations included in the efficiency frontier is small regardless of the number of observations in the sample and in the classical inferential context this constitutes an inefficient use of all information.

FIGURE 1



(2) Issues related to data's source and nature can be seen in Alves (1986, pp. 275-280).

FIGURE 2



2.1 — Proposed measures of factor efficiency

Two different firm specific measures of factor efficiency denoted by EF_1 and EF_2 are calculated for the purpose of analyzing efficiency in the manufacturing industries of Minas Gerais. The measure EF_1 is obtained by comparing an observed input coefficient point for a firm with an input coefficient on the efficiency frontier along a given ray from the origin. In figure 2 the ratio of distances *OC/OF* is the measure of firm *F*'s relative technical efficiency EF_1. It shows the observed output relative to the amount obtained by employing the observed amount of inputs with frontier-function technology or the relative reduction in input requirements by producing the observed output with frontier production technology and the same factor proportions. The EF_1 measure can be computed for all firm observations and as the ratio approaches unity, maximum technical efficiency for the firm is approached.

The second measure consists of an alternative procedure to the previous measure of factor efficiency. The EF_2 measure, like the previous one, is computed for all firm observations and the maximum revealed efficiency is reached when the index approaches unity. However, in order to minimize some of the method's limitations I have used a thick isoquant corresponding to the area between two consecutive efficiency frontiers for each industry. The first efficiency frontier, which was used in the calculation of EF_1, corresponds to the envelope for all establishments contained in the particular case. The second efficiency frontier is the envelope determined by the rest of the establishments, once those located on the first frontier have been eliminated (3).

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(3) Timmer (1970) has suggested the elimination of a certain percentage of the total «*n*» observations as a form to deal with the possibility of measurement error influencing the estimates. However, the discarding of observations will not be adopted here because this procedure presumes a rather large number of observations for every industry.

3 — Empirical analysis of efficiency input frontier (4)

Table 1, corresponding to the first efficiency frontier, and table 2, corresponding to the area between the first and second efficiency frontiers, illustrate the wide range of relative technical efficiency among most manufacturing establishments (5). The results have been condensed at the industry level for 18 industry groups. It can be seen that at the first efficiency frontier in each industry, 36.6 percent of the industrial establishments have a relative technical efficiency of less than two-fifths, and 61.9 percent less than three-fifths of that achieved by the establishments located on the efficiency frontier.

Even when an arbitrary «efficiency zone» instead of an efficiency frontier is used as a point of reference, a wide range of relative technical efficiency among establishments has also shown up. According to table 2, 47.7 percent of the industrial establishments have a relativa technical efficiency of less than three-fifths of that achieved by the establishments located on the thick isoquant. These results suggest that widespread inefficiency exists in the state's manufacturing sector, and this can be considered as evidence of substantial X-inefficiency. Moreover, this is broadly consistent with other recent studies of industrial enterprises in less developed areas which have indicated that there is substantial scope for improvements in the technical efficiency of their industrial firms (6).

Within each industry there is substantial variation in the individual indices of efficiency compiled either from the first efficiency frontier or from an efficiency zone. According to table 1, the three industries with the greatest number of firms with technical efficiency of less than three-fifths of that achieved by the respective establishments located on the efficiency frontier were: fabricated metals (96.89 %), metal and wood furniture (88.9 %) and animal butchering and preparation of meat (87.5 %). On the other hand, in industries such as printing, publishing and paper; pharmaceutics and perfumery; and beverages only 26.7 %, 28.6 % and 33.3 %, respectively, of the establishments have a relative degree of efficiency under three-fifths. In general, half of the industries (9 out of 18) have fifty percent or more of their establishments with relative efficiency under three-fifths.

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(4) Figures showing the scatter of points obtained by ploting the capital and labour-coefficients for different industries can be seen in Alves (1986, appendix 4).

(5) The relatively small samples involved in some of the industries such as beverages, clothing, dairy products, footwear and leather, and pharmaceutics and perfumery suggest caution before reaching strong policy conclusions. Further, it should be noted that some of the selected industries are not completely homogeneous.

(6) Compare the results reported in Meller (1979) for Chilean firms, and in Baah-Nuakoh (1980) for Ghanaian firms. Pack (1984) also found technical inefficiency for the Philippines firms, using a different but compatible methodology.

As far as the figures from table 2 are concerned, it can be seen that the rank of the industries was almost the same as compared to table 1. The only exception was the replacement of «metal and wood furniture» by «other food products» in the industry group with the greatest number of firms with relative technical efficiency of less than three-fifths. However, as it would be expected, the use of an efficiency zone and not an efficiency frontier as a point of reference resulted in an increase of the overall level of technical efficiency. Now, there are only 6 industries in which the percentage of establishments with relative efficiency under three-fifths is 50 percent or more.

TABLE 1

Relative efficiency in Minas Gerais manufacturing: EF_1

Industry	Number of establishments	Establishments on frontier	Range of efficiency coefficients (EF_1)			
			1.00 — .80	.79 — .60	.59 — .40	.39 — .00
1 — Metal and wood furniture	9	1	1	–	4	4
2 — Woven fabrics and theread	35	2	3	6	21	5
3 — Clothing	8	2	3	2	2	1
4 — Animal butchering and prep. of meat	16	1	1	1	7	7
5 — Dairy products	9	1	2	2	2	3
6 — Sugar refining and processing	11	3	5	2	2	2
7 — Other food products	25	2	4	2	6	13
8 — Footwear and leather	8	2	3	2	1	2
9 — Beverages	6	2	2	2	1	1
10 — Printing and publishing; and paper	15	5	7	4	1	3
11 — Pharmaceutics and perfumery	7	2	2	3	–	2
12 — Non-metallic minerals	21	2	4	7	7	3
13 — Iron and steel	21	3	11	2	4	4
14 — Fabricated metals	31	1	1	–	4	26
15 — Chemicals	9	3	4	1	–	4
16 — Mechanics	20	2	2	5	3	10
17 — Transport equipment	11	2	3	1	3	4
18 — Other manufacturings (*)	19	3	5	2	3	9
All MFG	281	39	63	44	71	103
Relative (%)	–	–	22.4	15.7	25.3	36.6

(*) Include establishments from the following industry groups: plastics, electrical equipment and miscellaneous industry.

Source: Author's computation from micro data file.

TABLE 2

Relative efficiency in Minas Gerais manufacturing: EF_2

Industry	Number of establishments	Establishments on frontier	Range of efficiency coefficients (EF_2)			
			1.00—.80	.79—.60	.59—.40	.39—.00
1 — Metal and wood furniture	9	4	4	3	2	–
2 — Woven fabrics and theread	35	5	7	7	18	3
3 — Clothing	8	4	4	1	2	1
4 — Animal butchering and prep. of meat	16	3	3	3	7	3
5 — Dairy products	9	3	3	2	3	1
6 — Sugar refining and processing	11	6	7	1	2	1
7 — Other food products	25	6	6	2	8	9
8 — Footwear and leather	8	4	5	1	1	1
9 — Beverages	6	4	4	1	–	1
10 — Printing and publishing; and paper	15	6	8	4	–	3
11 — Pharmaceutics and perfumery	7	5	5	1	1	–
12 — Non-metallic minerals	21	6	6	7	5	3
13 — Iron and steel	21	6	12	4	2	3
14 — Fabricated metals	31	5	5	2	6	18
15 — Chemicals	9	5	5	1	2	1
16 — Mechanics	20	5	6	2	5	7
17 — Transport equipment	11	4	4	2	1	4
18 — Other manufacturings (*)	19	6	6	3	3	7
All MFG	281	87	100	47	68	66
Relative (%)	–	–	35.6	16.7	24.2	23.5

(*) Include establishments from the following industry groups: plastics, electrical equipment and miscellaneous industry.

Source: Author's computation from micro data file.

As far as the mean efficiency of the state's manufacturing industry as a whole is concerned, the magnitudes of 53 % (EF_1) and 65 % (EF_2) are comparable to the 62 % average efficiency found for all Brazilian industry [Lee and Tyler (1978)], but are higher than the 47 % found by Baah-Nuakoh (1980) for Ghana. At the level of individual industries the magnitudes found for:

i) Iron and steel [69 % (EF_1) and 75 % (EF_2)] are higher than the 57 % found by Tyler (1979) for Brazil;

ii) Weaving [54 % (EF_1) and 62 % (EF_2)] are comparable to the 61 % found by Pitt & Lee (1981) for Indonesia;

iii) Dairy products [56 % (EF_1) and 63 % (EF_2)] are near to the 66 % found by Broeck et al. (1980) for Sweden;

iv) Mechanics [45 % (EF_1) and 57 % (EF_2)] are lower than the 69 % found by Page, Jr. (1984), for India.

The following main conclusion can be drawn from the above analysis. The evidence that a large number of establishments using very inefficient production techniques somehow manage to survive can be interpreted as being more than adequate to warrant that market forces do not penalize inefficiency. The existence of *X*-inefficiency in the manufacturing industries of Minas Gerais suggests that competition may not be perfect, either in the product of factor markets. Therefore it must constitute a matter of special interest to developing areas the possibility of increase an industry's production merely by raising the techinical efficiency of the less efficient establishments without any increase in the amount of productive factors. Next section attempts to explain the coexistence of establishments with great discrepancies in their efficiency levels through an econometric analysis of the determinants of the relative efficiency found in the state's manufacturing industries.

4 — Sources of technical inefficiency

4.1 — Definition and interpretation of the regression coefficients

The dependent variables to be used in the analysis of sources of inefficiency are the proposed measures of factor efficiency set out in section 2 and computed in section 3.

We turn now to the examination of the possible explanations for differing levels of efficiency. Normally, this is a question of the exercise of managerial capabilities. As such, it would be useful to examine efficiency differences in the context of management characteristics such as training, background, and motivation. Unfortunately such information is not totally available from our micro data file. However, the data set derived from our sample provides information on a number of establishment characteristics which might be related to the measured level of technical efficiency, such as: nationality of ownership, firm size, dimensions of domestic market structure, foreign trade participation and firm spatial location.

Because much of the literature on *X*-inefficiency has focused on the role of product market distortions and non-competitive environment, it is important to analyse the effects of market structural variables on efficiency. Conventional industrial organization theory recognizes market concentration and barriers to entry amongst the most important market structural variables influencing firm performance. The basic measure of concentration used in our multivariate regression equations is:

*CR*2: the sales share of the largest two establishments; and *CR*4: the sales share of the largest four establishments.

Concentration, however, is simply one dimension of market structure and is not of itself a measure of monopoly or market power. Another major dimension is the height of entry barriers, which is determined in part by technical factors such as the extent of production economies of scale relative to the size of the market, the absolute amount of capital required to operate a plant of minimum efficient scale, and other absolute production cost disadvantages of new entrants. The existence of significant barries to entry of new firms may strengthen the market power held by firms in concentrated industries. In the present analysis we use the following measure as a barrier to entry:

CAPINT: the ratio of book value of fixed assets to labour engaged.

Normally one would expect that competition in the domestic product market tends to improve factor efficiency. The process of competition tends to eliminate high cost producers, while the substantial market power often allows firms to remain in business. Moreover, the process of competition by mounting pressures on firms profits tends to discipline managements and employees to utilize their inputs and put forth more effectively than is the case where the competitive pressures are absent.

We would also expect efficiency to be affected by such factor as the degree of foreign competition two sort of measures representing such competition were used: the firm's exportation capability and the effective protection. There are three dimensions of manufacturing exportation as an indication of industrial efficiency: presence, changes and variety. In the present analysis we will use the first dimension as a measurement of the extent of involvement of an establishment in the export market. For such we use the following dummy variable:

DEXPT: a dichotomous variable = 1 if the establishment belongs to the state's seventieth largest exporters; otherwise = 0.

Insofar as the subjection of home producers to foreign competition tends to improve factor efficiency, the variable *DEXPT* should have a positive effect on the efficiency of the state's manufacturing industry.

The existence of barriers to imports reduces or even eliminates the pressure of foreign competition. Protection not only permits domestic production that cannot compete with imports, but also permits domestic production, at non-competitive costs, that could compete with imports if such competition were necessary for survival. Protection is thus a necessary condition for the existence of much *X*-inefficiency. Consequently, there should be a negative relationship between protection and efficiency. For analysing protection afforded in the domestic market we have employed the effective rate of protection *(ERP)* estimates computed by Tyler (1983, table A.1) which refer to the 1980-1981 period.

We also wish to examine the influence of the size of the firm on the efficiency of the state's manufacturing industry. It is normally accepted that large firms are often more efficient than small firms. This has been attributed to economies with respect to organization and technical knowledge and to firm growth resulting from past efficiency. To measure the firm size effect we use the following variables:

SIZE: the share of establishment's sales in the total three-digit industry sales;

*DSIZE*1: a dichotomous variable = 1 for establishments with a total labour force of less than 100; otherwise = 0; and

*DSIZE*2: a dichotomous variable = 1 for establishments with a total labour force of more than 500; otherwise = 0.

Another important policy issue for many developing areas is the extent to which the nationality of ownership of enterprises results in higher levels of technical expertise and greater efficiency. This issue has been a topic of considerable interest in the literature on economic development. It is frequently hypothesized that foreign firms are relatively more efficient compared to either private domestic firms or government firms. Superior technology and better management, frequently along *X*-efficiency lines, are thought to result in greater relative efficiency for foreign firms. In fact it is their greater relative technical efficiency which is frequently used to justify multinational firm operations in developing areas. To test for the importance of ownership as determinant of technical efficiency the following dummy variables for multinational and government firms were introduced into the regression equations:

*DOWN*1: a dichotomous variable = 1 for government owned establishments; otherwise = 0; and *DOWN*2: a dichotomous variable = 1 for foreign owned establishments; otherwise = 0.

Concurrently, an attempt was made in order to ascertain to what extent differences in the characteristics of the product are related to higher or lower levels of efficiency. For such, two dummy variables were used to indicate the use to which the product is put:

*DUSE*1: a dichotomous variable = 1 if the establishment belongs to intermediate goods industries; otherwise = 0; and *DUSE*2: a dichotomous variable = 1 if the establishment belongs either to consumer durable goods or to capital goods industries; otherwise = 0.

Finally, another variable thought related to efficiency is the establishment's spatial location. The analysis of the sources or technical efficiency in a spatial context was done through the following specific measure:

DRMBH: a dichotomous variable = 1 for establishments in the Belo Horizonte Metropolitan Region; otherwise = 0.

The maintened hypothesis is that the establishments in Belo Horizonte Metropolitan Region will exhibit lower indices of techinical efficiency.

4.2 — Model specification and estimation procedure

To test for the statistical significance of the proposed sources of inefficiency the following stochastic side relation forms were used:

$$EF_1 = a_1 + b_1CR2 + c_1CR4 + d_1CAPINT + e_1DEXPT + f_1ERP + g_1SIZE + h_1DSIZE1 + j_1DSIZE2 + k_1DOWN1 + l_1DOWN2 + m_1DUSE1 + n_1DUSE2 + p_1DRMBH + u_1 \quad (1)$$

$$EF_2 = a_2 + b_2CR2 + c_2CR4 + d_2CAPINT + e_2DEXPT + f_2ERP + g_2SIZE + h_2DSIZE1 + j_2DSIZE2 + k_2DOWN1 + l_2DOWN2 + m_2DUSE1 + n_2DUSE2 + p_2DRMBH + u_2 \quad (2)$$

where a_i $(i = 1$ and 2) are constants, b_i, c_i, d_i, e_i, f_i, g_i, h_i, j_i, k_i, l_i, m_i, n_i, *and* p_i $(i = 1$ and 2) represent the estimated coefficients of the independent variables (*CR2,. . ., DRMBH,* and u_i $(i = 1$ and 2) are the disturbance terms.

In estimating the regression coefficients of equations (1) and (2) we have used ordinary least squares. All the variables, whenever possible, are in logarithimic form (7). The logarithmic functional form very often reduces heteroscedasticity.

Before estimating the multivariate regression equations we should consider the possibility that a number of explanatory variables included in the analysis may be collinear to some extent. In such case, none or very few estimated coefficients would be statistically significant and the separate effects of each of the individual explanatory variables could not be distinguished. This prompted us to look for multicollinearity in our data. A look at the correlation matrix of the selected variables, given in table 3, may be helpful for the purpose. It is seen that the two concentration ratio variables are highly correlated. This table also shows significant correlation between *SIZE,* and the two size dummy variables (*DSIZE*1 and *DSIZE*2); *DSIZE*2 and *DEXPT*; *CR*2 and *DUSE*2; and *CR*4 and *DUSE*1. None of the other variables seem to be strongly intercorrelated. However, in some cases where we detect multicollinearity it was possible to drop one of the collinear variables without commiting a specification bias. That is, no significant relationship was observed between these variables and EF_1 or EF_2 in a bivariate regression analysis. Thus, although no definite conclusion can be drawn from these correlation comparisons alone, it seems that the problem of multicollinearity is not very damaging here.

(7) The only exceptions were *ERP* and dummy variables because some of the establishments had negative or zero values for these variables.

TABLE 3

Matrix of simple correlation coefficients among the selected variables

	SIZE	*DSIZE1*	*DSIZE2*	*CR2*	*CR4*	*ERP*	*DEXPT*	*CAPINT*	*DOWN1*	*DOWN2*	*DRMBH*	*DUSE1*	DUSE2
SIZE	1.00												
DSIZE1	— .47	1.00											
DSIZE2	— .46	— .29	1.00										
CR2	— .02	.11	— .02	1.00									
CR4	— .05	.10	— .04	.91	1.00								
ERP	— .03	.11	.00	.19	.18	1.00							
DEXPT	.21	— .19	.36	.11	.13	.06	1.00						
CAPINT	— .14	.27	— .02	.18	.17	— .06	.06	1.00					
DOWN1	.19	— .09	.20	.10	.10	.05	.16	.23	1.00				
DOWN2	.22	— .09	.32	.16	.14	.13	.32	.10	— .04	1.00			
DRMBH	— .04	— .00	.16	.07	.07	.12	.02	— .00	— .01	.11	1.00		
DUSE1	— .26	.06	.08	.25	.39	— .03	.18	.21	.10	.05	.12	1.00	
DUSE2	— .10	.02	.00	.37	.18	.23	— .02	.04	.06	.18	.07	— .28	1.00

Source: Same as table 1.

4.3 — Empirical results

Tables 4 and 5 report the results of the most successful attempts to explain variations in relative efficiency. The values for the multiple coefficient of determination, adjusted for degrees of freedom, range from .27 to .31 and are comparable with other attempts at regression analysis of efficiency indices [see, e. g., Page, Jr. (1984), Martin & Page, Jr. (1983), Pitt & Lee (1981), Baah-Nuakoh (1980), and Tyler (1980 and 1979)]. Further, it must be kept in mind that we are dealing with cross section analysis which normally shows lower R^2 values because of both the great variability that is possible across the individual entities and the lack of a common underlying trend [see, e. g., Intriligator (1978, p. 126)]. That the regression relationships are not meaningless and spurious can be seen from the confortable values of F-ratios which are all significant at the .01 percent level. Moreover, the coefficients of the independent variables for which the signs could be determined a priori have the right signs in all the equations, with the exception of concentration ratio. In addition, almost all the coefficients are statistically significant at the 5 percent or higher level of confidence. Lower levels of significance were only detected for the variables *DOWN*2 and *DUSE*1 in the regression equations for EF_1 and *DOWN*2 for EF_2.

A number of interesting results emerge from the multiple regression equations which relate technical efficiency to various combinations of the explanatory variables. As indicated in tables 4 and 5, the *SIZE, CAPINT, ERP* and *CR*2 variables have a strong influence on technical efficiency, measured either in terms of EF_1 or EF_2. Their regression coefficients are highly significant (more than 1 % in all equations) even when all other variables are included and, in addition, the estimated coefficients of such variables are very stable.

The results suggest that larger firms are more efficient than smaller firms confirming Tyler's (1979) finding for the Brazilian plastics and steel industries, Pitt & Lee's (1981) finding for the Indonesian weaving industry and Page's (1984) finding for the Indian machine tools industry. Moreover, using our *SIZE* measure as an indicator of market share, it appears that the more efficient establishments in the state's manufacturing industry tend to possess larger shares of the total market than less efficient establishments. A question not answered by the analysis is whether these establishments became large in part because of high technical efficiency in the past.

However, when we try to include the other two size explanatory variables (*DSIZE*1 and *DSIZE*2) in equations (5) [table 4] and (4) [table 5] the problem of multicollinearity, previously referred to, seems to appear by changing the signs of the two dummy variables designed to measure the influence of size [8].

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[8] As a check on the impact of multicollinearity, the multiple regressions for EF_1 and EF_2 were re-run deleting *SIZE* as an explanatory variable. As a result we get the right signs for *DSIZE*1 (negative) and *DSIZE*2 (positive). While the dummy variable designed to measure the influence of establishments with a total labour force < 100 is statistically significant at the 10 percent level

TABLE 4
Regression equations for EF_1

Independent variables	(1)	(2)	(3)	(4)	(5)
SIZE	.160 (6.917)	.143 (5.940)	.151 (6.106)	.154 (5.942)	.186 (6.126)
*DSIZE*1	–	–	–	–	.099 (.933)
*DSIZE*2	–	–	–	–	— .193 (— 1.866)
*CR*2	.339 (4.007)	.312 (3.692)	.319 (3.772)	.312 (3.591)	.285 (3.261)
ERP	—2.93-03 (— 4.523)	—3.08-03 (— 4.763)	—3.01-03 (— 4.647)	—2.98-03 (— 4.570)	—3.09-03 (— 4.715)
DEXPT	–	.202 (1.925)	.223 (2.106)	.214 (1.977)	.269 (2.430)
CAPINT	— .192 (— 5.655)	— .202 (— 5.939)	— .189 (— 5.348)	— .190 (— 5.353)	— .202 (— 5.515)
*DOWN*1	–	–	— .318 (— 1.373)	— .326 (— 1.401)	— .260 (— 1.114)
*DOWN*2	–	.183 (1.086)	.140 (.819)	.139 (.814)	.203 (1.170)
DRMBH	— .173 (— 2.351)	— .185 (— 2.517)	— .184 (— 2.513)	— .188 (— 2.538)	— .161 (— 2.148)
*DUSE*1	–	–	–	.034 (.402)	.067 (.790)
Constant	— 1.882	— 1.791	— 1.831	— 1.814	— 1.735
$\bar{R}^2$	.295	.306	.309	.307	.313
F	24.47	18.67	16.62	14.75	12.58

Notes:

i) *t*- statistics are in parentheses. Tests of significance are made on the basis of one--tailed test.

ii) A coefficient followed by a number with a hyphen indicates the decimal point is placed that number of places to the left.

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either for EF_1 or EF_2, implying that smail establishments are less efficient; the *DSIZE*2 coefficient is not significant. Moreover, the deletion of the variable *SIZE* had the effect of lowering both the R^2's and the *F*-values.

The hypothesis that establishment enjoying absolute capital requirements barrier tend to be less technically efficient seems to be strongly supported by our empirical results. Thus, according to tables 4 and 5, the existence of significant barries to entry of new firms may strengthen the market power held by the dominant firms and, consequently, may have a significant effect on the choice of tecnhology. That is, firms may lax in maximizing technical efficiency when the discipline of competition is weak.

TABLE 5

Regression equations for EF_2

Independent variables	(1)	(2)	(3)	(4)
SISE	.154 (7.864)	.145 7.221)	.142 (6.922)	.182 (7.653)
DSIZE 1	–	–	–	.129 (1.461)
DSIZE 2	–	–	–	— .250 (— 2.945)
*CR*2	.272 (3.796)	.258 (3.603)	.253 (3.513)	.230 (3.230)
ERP	— 1.22–03 (— 2.218)	— 1.29–03 (— 2.351)	—1.33–03 (— 2.414)	— 1.48–03 (— 2.711)
DEXPT	–	.188 (2.184)	.170 (1.909)	.260 (2.836)
CAPINT	— .131 (— 4.542)	— .136 (— 4.723)	— .138 (— 4.777)	— .148 (— 5.038)
*DOWN*2	–	–	.111 (.773)	.182 (1.272)
DRMBH	— .124 (— 1.981)	— .127 (— 2.041)	— .132 (— 2.108)	— .092 (— 1.469)
Constant	— 1.506	— 1.465	— 1.440	— 1.373
$\bar{R}^2$	.272	.282	.282	.304
F	21.90	19.30	16.60	14.62

Notes: Same as notes to table 4.

In the light of the discussion in the preceding paragraph it is useful to analyse whether protection is really a necessary condition for the existence of much *X*-inefficiency. The coefficients of the effective rate of protection variable are of expected signs in all the equations of tables 4 and 5. High levels of effective protection for domestic market sales are reflected in lower technical efficiency in the state's manufacturing industry. This result supports Weil's (1973) observation that lack of competitive pressure due to high tariffs and significant barries to entry allow firms to choose inappropriate technology.

The estimated coefficients for *CR*2, while highly significant, has a positive sign throughout, which does not coincide with a priori expectations. One possible explanation for this result is that the concentration ratio may not reflect the degree of market power excercised by the largest establishments but may reflect economies of scale and specialization. As emphasized by Page (1984), the concentration and size variables, when included with other establishment attributes, are intended to summarize the effects of omitted variables associated with scale and product differences on the index of techical efficiency. The most obvious of these efects arises from the inability of the estimation procedure to allow for variable returns to scale. Increasing returns to scale will be reflected in greater measured technical efficiency, and thus in our sample the *SIZE* and *CR*2 variables may be associated with improvements in measured technical efficiency, controlling for other variables.

As far as the other explanatory variables are concerned, the results suggest that when the establishment belongs to the state's largest exporters groups it constitutes a significant factor in explaining an establishment's position relative to the industry efficiency frontier. The coefficient estimates for *DEXPT* conformed to the expected sign (positive) and were continuously significant at the 5 percent level or above. Thus, as might be expected the ability to compete in international markets would result in an efficient pattern of industrial growth.

The spatial firm dummy variable was also introduced into the equations in both tables. In all equations, its estimated parameters are significant at the 2.5 percent level or above (9). The *DRMBH* coefficients have negative signs throughout, which does coincid with a priori expectations. That is, establishments in the Belo Horizonte Metropolitan Region exhibit lower indices of technical efficiency.

The question of the relative efficiency of foreign firms and government owned firms is also explored. It is frequently argued that foreign firms display greater efficiency because they enjoy better management and possess greater access to foreign technology. On the other hand, public enterprises are frequently seen as inefficient operators due to the lack of market discipline and government interference in managerial practices and recruitment [see, e. g., Tyler (1979)]. As seen in table 4, the estimated coefficients for *DOWN*1 and *DOWN*2, while showing the right signs, were only estatistically significant at the 10 percent level for equations (3) and (4) [*DOWN*1] and at the 15 percent level for equation (5) [*DOWN*2]. When we allow for the possibility of errors in the extreme observations (table 5) only the dummy variable for foreign owner-

(9) In the regression equation (4) of table 5, when all the selected explanatory variables are included, this coefficient lowered its significance level to 10 percent.

ship was introduced into the regression equations. But it was only in the equation (4) that the coefficient was significant at the 15 percent level. Thus, in the present sample the evidence is not completely conclusive in relation to the hypothesis that foreign firms are significantly more efficient than domestically owned private firms, or that government firms are less efficient.

5 — Summary and conclusion

The analysis carried out in this paper has attempted for the first time to explore the issue of efficiency performance in the manufacturing industry of Minas Gerais. For such, a micro data file consisting of 281 observations for a cross-section of manufacturing firms was employed.

The estimation technique allowed the computation of two firm specific measures of technical efficiency. Our results can be used as an evidence that market forces do not penalize inefficiency, insofar as a large number of establishments using very inefficient production techniques coexist with efficient establishments in the state's industrial sector.

In the light of such results and in order to explain the sources of X-inefficiency we have explored the relationship between efficiency and a number of firm specific atributes. For the most part, as we have seen, the regression analyses were highly conclusive. Several clearcut and strong associations could be discerned.

The principal results may be summarized as follows: lack of competitive pressure either due to high levels of effective protection for domestic market sales or to significant barries to entry allows firms to choose inapropriate technology; ability to compete in the international market is positively associated with technical efficiency; larger firms tend to be more efficient than smaller firms; establisments in the Belo Horizonte Metropolitan Region exhibit lower indices of technical efficiency; and no conclusive evidence in relation to the hypothesis that foreign firms are significantly more efficient than domestically owned private firms, or that government firms are less efficient was reached.

As for policy implications a major theme stands out in the analysis. Given the importance of product market structure in the determination of technology choice and factor efficiency in Minas Gerais, distortions in this area may put artificial constraints on the choice of techniques and prevent the entrepreneurs from perceiving the whole range of available technique. Thus, whenever a new industrial plant is set up in a region like Minas Gerais or even in the country as a whole, every effort must be made to obtain such a blue print as will suit the local factor endowments. But the structure of incentives must be such as to force entrepreneurs to look for the appropriate and most efficient technology. Moreover, our findings can be also important in the current debate on the alternatives to the Brazilian industrial sector insofar as it seems that medium and long-term prospects of this sector depend on its overall efficiency and its ability to compete domestically and abroad. Finally, it should be stressed that this analysis does not mean that neither improvements in the methodology nor further inquiry in the state's manufacturing efficiency are no longer necessary. We would not claim to have identified all the channels through which public policy could impinge on X-inefficiency. Moreover, the approach used in this paper, being non-parametric, lies outside what might be called the more conventional statistical framework. In order to frame adequate policy to reduce X-inefficiency a better understanding must exist as to its nature and causes. For such, it would be useful to develop more explicit models of economic behaviour relating to efficiency, with the use of a more complete data set.

6 — References

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ALVES, Paulo S. M — **Mensuração e fontes de eficiência técnica na indústria manufactureira: um estudo de caso para o Brasil.**

Este texto visa proporcionar alguma evidência empírica sobre a questão da eficiência técnica na indústria manufactureira do Brasil, a partir de informações desagregadas a nível de estabelecimento. Para tanto, como uma alternativa metodológica às estimativas econométricas da função de produção, fez-se uso do método da «função de fronteira eficiente». Após concluir que um grande número de estabelecimentos utilizando técnicas ineficientes de produção coexistem com estabelecimentos eficientes dentro do sector industrial, desenvolvemos uma análise das fontes de eficiência técnica.

ALVES, Paulo S. M. — **The measurement and sources of technical efficiency in the manufacturing industry: a case study.**

This paper seeks to shed some empirical light on the issue of technical efficiency in the Brazilian manufacturing industry based upon an examination of data at the establishment level. For this task, we made use of the frontier function method, as an alternative to the methodology of production function's econometric estimation. After concluding that a large number of establishments using very inefficient production techniques coexist with efficient establishments in the industrial sector, an analysis of the sources of technical efficiency was carried out.