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DISCUSSION PAPER

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Federal Government of Brazil

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DISCUSSION PAPER

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TECHNICAL EFFICIENCY IN BRAZILIAN MANUFACTURING ESTABLISHMENTS: RESULTS FOR 1970 AND 1980

Armando Castelar Pinheiro

1. INTRODUCTION

II. METHODOLOGY

III. DATA

IV. EMPIRICAL RESULTS

V. FINAL REMARKS

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ABSTRACT

The objective of this paper is to identify variables that influenced the efficiency level of Brazilian manufacturing establishments in 1970 and 1980. Efficiency is defined as the ratio of actual to best practice output, which is measured using deterministic translog frontier production functions. Maximum likelihood estimators are obtained for each sector. Thirteen variables are examined, with trade orientation and, especially, industrial structure showing to be significantly associated with efficiency.

TECHNICAL EFFICIENCY IN BRAZILIAN MANUFACTURING ESTABLISHMENTS: RESULTS FOR 1970 AND 1980 [1]

ARMANDO CASTELAR PINHEIRO

1) Introduction

The Brazilian development strategy of the 1990's will have to stress the search for efficiency, rather than the emphasis on factor accumulation that characterized the past. The government will have to rely on a new set of instruments and economic policy will have to be redesigned. In this context, issues such as import liberalism, export promotion, and domestic competition -- and their impact on efficiency -- will be in the heart of the debate.

The objective of this paper is to identify variables that have historically influenced the efficiency level of Brazilian manufacturing establishments. The analysis is based on data from the industrial censuses of 1970 and 1980. Efficiency is defined as the ratio of actual to best practice or potential output, with the latter being measured with the use of deterministic frontier production functions.

Frontiers were estimated for Brazilian manufacturing in the aggregate by Lee and Tyler (1978) and at sectoral level by Tyler (1978,1979) and Braga and Rossi (1986). Studies for different sectors in the manufacturing industry were also conducted by Rossi (1984) for Sao Paulo and by Alves (1987) for Minas Gerais. Our study, however, is the first to simultaneously use maximum likelihood estimates, to consider a true production function, to use a flexible functional form (translog), and to work with a three-digit sectoral disaggregation of the manufacturing industry.

For each sector, we correlate efficiency at firm level with a set of thirteen variables, ranging from trade bias to labor force composition and size, with the objective of identifying those that influenced the efficiency of firms in 1970 and 1980.

The plan of the paper is the following. In section 2 we briefly review the methodology to be applied. In section 3 we describe the data to be used in the frontier estimation and the variables that we think can be related to the establishment's efficiency level. The correlations with efficiency are presented and analyzed in section 4. Finally, in section 5, we summarize the conclusions reached in the paper.

2) Methodology

Frontiers can be classified according to at least three different criteria: first, whether or not a functional form is assumed for the frontier -- nonparametric frontiers being less restrictive; second, according to whether or not the residuals are assumed to be all one-sided -- probabilistic and stochastic frontiers allow some firms to be "super-efficient"; third, depending on whether or not any assumption is made with respect to the probability distribution of the residuals.

In a parametric deterministic frontier, as the one used here, all establishments must lie on or below the frontier. A formal representation is given by:

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1 - This paper is a summary of Chapter 4 of my Ph.D. dissertation, and has benefited from the comments made by Albert Fishlow, Bronwyn Hall, and Sherman Robinson; and from computer assistance by Marcia Pimenel Pinto.

$$\ln Y = \ln f(X) - u, \qquad u \geq 0 \qquad (1),$$

where, Y is the actual output of the firm, f(X) is the frontier production function, and e^{-u} is the establishment's efficiency level $(0 < e^{-u} \leq 1)$.

We specify ln f(X) as a translog production function, which can be described by:

$$\ln(f(a, X)) = a_0 + a'Z + Z'A Z =$$

$$= a_0 + \Sigma_j^4 a_j \ln(X_j) + 1/2 \Sigma_k^4 \Sigma_j^4 a_{jk} \ln(X_j) \ln(X_k) \qquad (2).$$

Although flexible functional forms such as the translog can capture more closely the actual technology, it is not unusual in empirical studies to find oneself with estimates that do not meet the requirements for f(.) to represent a frontier production function; that is, to be concave and monotonically nondecreasing.[2] To guarantee that our translog represents a true production function, we require that the parameters satisfy

$$\Sigma_j^4 a_j - 1 = 0 \qquad (3); \qquad \Sigma_j^4 a_{jk} = 0, \; k=1,4 \qquad (4);$$

$$a_j \geq 0, \; j=1,4 \qquad (5); \qquad a_{jj} \leq 0, \; j=1,4 \qquad (6).$$

Restrictions (3) and (4) are necessary and sufficient to impose constant returns to scale to the translog, while (5) is necessary and sufficient to guarantee monotonicity at the approximation point. Assuming that (3), (4) and (5) hold, then (6) is both necessary and sufficient to guarantee global concavity.[3] It is worth pointing out, however, that attaining global concavity is not costless. In particular, as shown by Diewert and Wales (1987), we lose flexibility and run the risk of overestimating the elasticities of substitution between the inputs.

The parameters of the translog frontier described by (2) to (6) can be estimated by four different methods: linear programming, quadratic programming, corrected nonlinear least squares (CNLS), and maximum likelihood (ML). The first two are easier to apply, but provide estimates with unknown statistical properties. Even if the "right" distributions are assumed for the residual term u, the estimates obtained with these procedures will not necessarily be asymptotically unbiased and efficient.[4] The CNLS method provides consistent estimates (except for the intercept) with t-tests; however, since the method does not take into account the asymmetry of the error distribution, it is not usually efficient.

Maximum likelihood, the procedure adopted here, provides efficient estimates, in the sense that they take into account the one-sided nature of the distribution of the residual, have known statistical properties and can have their significance tested, at least asymptotically.

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2 - See Lau (1978), Christensen and Caves (1980), Jorgenson and Fraumeni (1981), Barnett and Lee (1985), Jorgenson (1986) and Diewert and Wales (1987) for discussions on concavity and monotonicity problems with flexible functional forms.

3 - A proof of necessity and sufficiency of these conditions for global concavity of the translog was first advanced by Jorgenson and Fraumeni (1981). It relies on the one-to-one correspondence between the elements of the matrix of (constant) share elasticities A (see expression (2)) and those of its Cholesky decomposition. For global concavity it is necessary and sufficient that the diagonal elements of the Cholesky factorization of A be non-positive, what in this case is equivalent to conditions (6). See Jorgenson (1986) for a more detailed proof and Lau (1978) for a discussion on imposing and testing monotonicity and concavity using Cholesky decompositions. Note the particular role played by the constant returns to scale assumption. See also Nishimizu and Page (1982) for an application using linear programming.

4 - If the error terms are i.i.d and exponentially (half-normally) distributed, the solution to the linear (quadratic) program will be a maximum likelihood estimate. See Schmidt (1976) and Pinheiro (1989) for further details.

The density of the inefficiency error was assumed to be a gamma because: (i) in this case the nice asymptotic properties of the maximum likelihood estimates are maintained, even though the support does depend on the parameters to be estimated (see Greene (1980a)); and (ii) the gamma distribution is very flexible, and it encompasses skewed and symmetric distributions.[5]

Then, we can define our estimation problem as finding a solution to

$$\text{Max}_{a,S,P}\ L^* = T\,[(P^2+2)\ \ln S^2 - \ln G(P^2+2))] + [(P^2+2)-1]\ \Sigma_i \ln(u_i) - S^2\ \Sigma_i\ u_i \quad (7);$$

s.t.

$$u_i = a_0 + \Sigma_j^4\ a^2_j.\ln(X_{ij}) + \Sigma_j^4\ \Sigma_{k>j}\ a_{jk}\ \ln(X_{ij})\ \ln(X_{ik}) - 1/2\ \Sigma_k^4\ a^2_{kk}\ \ln(X_{ij})^2 - \ln Y_i \geq 0$$

$$\Sigma_j^4\ a_j^2 - 1 = 0;$$

$$\Sigma_{k=j}\ a_{jk} - a_{kk}^2 = 0,\ k=1,4,\ j=1,4;$$

$$a_{jk} = a_{kj},\ k=1,4,\ j=1,4;$$

and where, G() is the gamma function.

3) Data

The data used in our analysis came from the Industrial Censuses of 1970 and 1980. The unit of observation in the Census is the establishment, defined as "the part of the organization that is in charge of the industrial activity and has installations and means to produce industrial goods." We selected establishments that had more than five employees and were active the entire year. Furthermore, since we will be working with logarithms, all establishments for which any of the inputs were equal to zero were deleted.

We considered only sectors with more than 20 establishments. This lower limit in the number of observations was imposed in order to allow for enough degrees of freedom. To control expenses with computer facilities, we took systematic samples for sectors with a large number of observations.

We work with four different inputs, namely capital, labor, material inputs and energy inputs. Output was defined straightforwardly as the current value of the goods and services produced by the establishment. We assume that the flow of capital services in each establishment is proportional to its stock of machinery, equipment and installations, which is our capital input variable. Labor is measured by a weighted average of the number of employees with different skills in the establishment. Material inputs are set equal to the value of goods and services consumed in production, including rents, freight and royalties -- no distinction is made between inputs that were domestically produced and those that were imported. Finally, the energy input was measured by the value of the establishment's expenses with electric energy and fuels.

Thirteen variables are used in the correlation analysis with efficiency levels. They are divided in four groups: trade related; labor composition; capital structure; and, loosely speaking, industrial characteristics. In Table 1 we define them.[6]

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5 - Needless to say that the reasons for choosing such distribution are far from satisfactory. Note, however, that there is no a priori reason in favor of any particular distribution for the error term. Any other choice would have been, therefore, equally arbitrary. See Greene (1980a) and Deprins (1986) for further details.

6 - For a detailed definition see Pinheiro (1989).

4) Empirical Results

To obtain a numerical solution to the maximization problem described by (7), we used the optimization software developed by Professors Richard Quandt and Stephen Goldfeld of Princeton University, in particular its subroutine GRADX.[7] Convergence was achieved for 99 sectors in 1970 and 104 in 1980; no convergence was achieved for 8 sectors in 1970 and for 5 sectors in 1980.

Results for the frontiers were somewhat frustrating. The error distribution was found to be symmetric for many sectors, with two important consequences. First, it reduced significantly the efficiency gains we had expected to achieve using the more expensive maximum-likelihood procedure. Second, to the extent that this symmetry reflected the importance of measurement errors, it was partly responsible for the somewhat poor correlations obtained.

7 - The program converges in case one of the following is less than accuracy: (i) the attempted change in the valueof each of the parameters, (ii) the norm of the gradient, and (iii) the relative improvement in the function value in any step. Accuracy was fixed at 1^{-10}.

TABLE 1

VARIABLES CORRELATED WITH EFFICIENCY

VARIABLE	DEFINITION
SHDEX	Share of output that is directly exported by the establishment.
SHIMI	Share of imports in the consumption of material inputs.
SHINV	Share of imports in the investment in machinery and equipment.
ROY	Ratio of the expenses with royalties to output.
MP	Male participation in the labor force.
SW	Proportion of skilled labor working directly in production.
CCS	Ratio between the stock of machinery, equipment and installations and the value of structures and site.
ILM	Ratio between the investment and the stock of machinery, equipment and installations.
RRM	Rate of return for the stock of machinery, equipment and installations.
SIZE	Value of the establishment's output.
CI	Capital intensity.
CU	Capital utilization.
PROF	Profitability.

It is interesting to observe, in this respect, that similar results have been reported in other studies. Braga and Rossi (1986) obtained skewed error distributions for only one-third of the 136 sectors of the Brazilian manufacturing industry they studied. A relatively symmetric distribution was also reported by Alves (1987).[8]

Trying to overcome this problem we re-estimated the frontiers with a reduced sample that included only establishments with more than fifty employees. Our assumptions were that not only heterogeneity across establishments would be reduced but also that less measurement error should be present. In fact, although a large number of sectors continued to show symmetrical error distribution, the degree of skewness generally increased.

8 - See also Aigner, Lovell and Schmidt (1977) and Tyler and Lee (1978).

Once efficiency for each establishment had been estimated, we tried to identify which variables were positively or negatively correlated with them.[9] In particular, we were interested in examining the association between trade and efficiency. After estimating the correlations between the explanatory variables and efficiency we had to report them in a concise fashion -- for every sector, we had results for 13 variables, two years and two working samples (i.e., a total of 52 correlations per sector and an equal number of p-values).

Thus, we decided to report the results in three different ways. Initially, we exam the interval distribution of all correlations, both significant and non-significant. Afterwards, we analyze the sign distribution of significant correlations.[10] Finally, we look at the sign distribution of significant correlations for the 30 most important sectors of Brazilian manufacturing industry.[11]

In Tables 2 and 3, we report the distribution of correlations for 1970, for the complete and the reduced samples, respectively. We observe that for several variables -- SHDEX, SHIMI, ROY, MP, SW and CCS -- the distribution of correlations is basically symmetric, and concentrated in the [-.1, .1] interval. These results suggest that for those variables there was not, in 1970, an industry-wide association with efficiency in any specific direction, neither for the complete nor for the reduced sample.

For RRM, PROF and SIZE, the distribution of correlations reveals a clear and generally positive association with efficiency. These distributions imply that, in 1970, efficient firms tended to be more lucrative and profitable, and that large firms were generally more efficient than small ones. Note, however, that for the SIZE variable the distribution of correlations is less skewed for the reduced sample.

On the other hand, we observe a clearly negative association between CI and efficiency for almost all sectors, for both samples, although less so for the reduced sample. More than one explanation can account for this result, including measurement errors, as we will see later.

Finally, a slightly positively skewed distribution of correlations was obtained for CU, SHINV and ILM. These correlations highlight the importance of capital utilization and composition (by origin and age, respectively) in determining the efficiency of the establishment.

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9 - Maddala and Fisher (1979) argue that if those relevant variables actually exist they should be included in the production function in order not to bias the remaining estimates. Although acknowledging that, we will stick to our correlation analysis to limit computational costs. It is worth noting, though, that of the studies reviewed only Chen and Tang (1987) actually follow that prescription.

10 - A 10% significance level was adopted and only correlations with more than eight degrees of freedom were considered.

11 - Results for the frontier estimates and the values of the correlations can be obtained from the author upon request.

TABLE 2

DISTRIBUTION OF CORRELATION COEFFICIENTS - 1970
(Complete Sample, Number of Employees > 5)

	SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
<-0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.7/-0.4	0	2	0	0	0	0	0	0	1	0	2	0	0
-0.4/-0.2	0	1	2	3	2	1	0	2	6	0	37	5	0
-0.2/-0.1	6	11	7	3	12	6	0	4	12	0	38	6	0
-0.1/0.0	44	14	24	58	30	48	0	23	37	1	15	25	0
<0.0	50	28	33	64	44	55	0	29	56	1	92	36	0
0.0/0.1	32	11	27	28	48	33	7	54	31	17	5	50	0
0.1/0.2	13	8	24	4	6	7	25	12	8	46	1	7	0
0.2/0.4	2	8	10	2	0	3	54	3	3	30	0	5	3
0.4/0.7	1	6	2	0	0	0	12	0	0	4	0	0	37
>0.7	0	0	0	0	0	0	0	0	0	0	0	0	58
>0.0	48	33	63	34	54	43	98	69	42	97	6	62	98
TOTAL	98	61	96	98	98	98	98	98	98	98	98	98	98

TABLE 3

DISTRIBUTION OF CORRELATION COEFFICIENTS - 1970
(Reduced Sample, Number of Employees > 50)

	SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
<-0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.7/-0.4	0	5	0	1	0	1	0	1	6	0	2	1	0
-0.4/-0.2	5	7	6	3	5	3	0	3	8	0	18	5	0
-0.2/-0.1	9	4	6	7	7	10	0	11	6	2	30	10	0
-0.1/0.0	23	10	17	37	23	19	0	9	12	9	17	13	0
<0.0	37	26	29	48	35	33	0	24	32	11	67	29	0
0.0/0.1	22	4	15	14	19	20	4	24	17	9	4	23	1
0.1/0.2	10	5	13	7	15	14	10	21	17	24	3	8	0
0.2/0.4	5	5	17	5	5	6	42	4	8	22	0	14	4
0.4/0.7	0	4	0	0	0	1	18	1	0	8	0	0	34
>0.7	0	0	0	0	0	0	0	0	0	0	0	0	35
>0.0	37	18	45	26	39	41	74	50	42	63	7	45	74
TOTAL	74	44	74	74	74	74	74	74	74	74	74	74	74

In Tables 4 and 5, we report the distribution of correlations between the explanatory variables and efficiency in 1980, for the complete and the reduced samples, respectively. We observe that for most variables -- SHINV, ROY, MP, SW, RRM, CCS, SIZE, CI, and PROF -- the distribution of correlations for 1980 parallels the one obtained for 1970. Therefore, most comments made about the variables for 1970 apply equally to 1980.

On the other hand, we observe that for CU the distribution of correlations becomes more symmetric (and concentrated in the [-.1, .1] interval), whereas for SHDEX, SHIMI, and ILM, it becomes more positively skewed, suggesting that in 1980 the interaction with international markets was more important in explaining differences in efficiency.

In the first row of each part of Table 6, we have the number of sectors with significant correlations in 1970, for the complete sample. Results here yield conclusions very similar to those obtained from the analysis of all correlations.

For the trade variables, we see that the share of imports in the investment in machinery and equipment (SHINV) was the variable for which a larger number of significant correlations with the expected sign was observed. For exports and imports of material inputs two-thirds of the observed significant correlations had the right sign. Only three sectors presented a positive and significant correlation between efficiency and the expenses with royalties as a share of output.

These numbers would seem rather small, had trade had a very significant influence on efficiency. Even for SHINV just about one-fifth of the sectors have shown a significant correlation. It is important to note, however, that in a closed economy like that of Brazil in 1970 few manufacturing sectors actually interacted in a significant way with international markets. This is well illustrated by the small number of establishments that reported a value for the consumption of imported material inputs. Besides that, one should keep in mind that our data covers only exports and imports (except for machinery and equipment) directly undertaken by the establishment.

For the labor-force-composition variables (MP and SW) the results are also consistent with those of Table 2. For less than 20% of the sectors the correlation was significant and of these more than half presented the "wrong" sign. The negative association between MP and efficiency is probably warranted by the "enlightenment" hypothesis advanced by Kendrick and Grossman(1980, p108).[12] Since differences in the skill composition had already been taken into account in the definition of the labor input, the results for SW may also not be so surprising after all.

The rate of return (RRM) and profitability (PROF) were significantly and positively correlated with efficiency for most sectors in 1970 -- these results are consistent both with intuition and with the skewed distributions of Table 2.

The ratio of investment to the stock of machinery and equipment (ILM) is positively and significantly correlated for about one-sixth of the sectors. Depending on the direction of causality, this result may reflect two different phenomena. First, efficient firms tend to invest more. Second, new capital embodies more efficient technology. For CCS, no systematic significant association existed with efficiency.

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12 - In short, their idea is that firms "with higher proportion of women may be the more 'enlightened' type of [firms] that are more prone to take advantage of technological and managerial advances".

TABLE 4

DISTRIBUTION OF CORRELATION COEFFICIENTS - 1980
(Complete Sample, Number of Employees > 5)

	SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
<-0.7	0	1	0	0	0	0	0	0	0	0	0	0	0
-0.7/-0.4	0	4	0	0	1	7	0	1	2	0	4	1	0
-0.4/-0.2	2	6	0	3	3	14	0	0	2	0	62	3	0
-0.2/-0.1	1	3	6	1	11	10	0	3	12	0	28	9	0
-0.1/0.0	25	12	32	52	39	14	0	17	43	0	6	41	0
<0.0	28	26	38	56	54	45	0	21	59	0	100	54	0
0.0/0.1	54	16	42	42	41	13	4	61	36	18	2	36	0
0.1/0.2	17	11	14	5	6	8	29	19	7	56	2	12	1
0.2/0.4	5	12	8	1	3	4	54	3	1	28	0	2	2
0.4/0.7	0	2	1	0	0	7	16	0	0	2	0	0	47
>0.7	0	1	0	0	0	0	1	0	0	0	0	0	54
>0.0	76	42	65	48	50	32	104	83	44	104	4	50	104
TOTAL	104	68	103	104	104	77	104	104	103	104	104	104	104

TABLE 5

DISTRIBUTION OF CORRELATION COEFFICIENTS - 1980
(Reduced Sample, Number of Employees > 50)

	SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
<-0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.7/-0.4	0	2	1	0	0	1	0	0	2	0	1	2	0
-0.4/-0.2	1	4	8	2	3	6	0	5	10	0	28	6	0
-0.2/-0.1	10	6	4	9	22	7	0	4	9	1	30	8	0
-0.1/0.0	19	8	15	49	24	14	0	23	26	4	20	26	2
<0.0	30	20	28	60	49	28	0	32	47	5	79	42	2
0.0/0.1	27	8	33	19	18	6	6	27	23	11	5	26	0
0.1/0.2	18	9	13	6	15	11	13	18	14	28	3	15	3
0.2/0.4	12	8	10	2	5	9	36	10	3	39	0	4	5
0.4/0.7	0	1	3	0	0	3	32	0	0	4	0	0	35
>0.7	0	0	0	0	0	1	0	0	0	0	0	0	42
>0.0	57	26	59	27	38	30	87	55	40	82	8	45	85
TOTAL	87	46	87	87	87	58	87	87	87	87	87	87	87

TABLE 6

SIGN DISTRIBUTION OF SIGNIFICANT CORRELATION COEFFICIENTS

		SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
		Number of Negative Significant Correlations												
1970	(1)	5	2	1	4	10	9	0	2	3	0	70	6	0
	(2)	5	3	2	2	4	3	0	5	8	0	18	5	0
	(3)	3	2	1	6	5	10	0	3	5	0	71	3	0
1980	(1)	0	6	1	6	18	9	0	2	6	0	88	4	0
	(2)	2	3	3	2	4	2	0	4	7	0	31	5	0
		Number of Positive Significant Correlations												
1970	(1)	10	6	21	3	4	5	89	16	1	75	0	12	98
	(2)	2	4	9	2	6	4	54	3	6	33	0	8	73
	(3)	5	7	11	4	8	5	93	15	2	37	0	6	101
1980	(1)	31	7	17	7	10	8	97	24	4	83	1	8	104
	(2)	10	4	11	4	6	3	65	7	0	48	1	4	83
		Total Number of Significant Correlations												
1970	(1)	15	8	22	7	14	14	89	18	4	75	70	18	98
	(2)	7	7	11	4	10	7	54	8	14	33	18	13	73
	(3)	8	9	12	10	13	15	93	18	7	37	71	9	101
1980	(1)	31	13	18	13	28	17	97	26	10	83	89	12	104
	(2)	12	7	14	6	10	5	65	11	7	48	32	9	83

(1) - Complete sample (>5 employees).
(2) - Reduced sample (>50 employees).
(3) - Complete sample, relaxing the constant-returns-to-scale restriction.

The SIZE variable was positively and significantly correlated with efficiency for about 80% of the sectors. This result highlights the importance of economies of scale as an explanation of efficiency. Furthermore, it is fully consistent with the literature, and gives support to either or both (i) Salter's (1966) hypothesis that the speed of technology absorption depends on firm size or (ii) the idea that different frontiers may exist for large and small firms.

Capital intensity (CI) presented a negative and significant correlation with efficiency for about three-fourths of the sectors, in 1970. A possible explanation for this could be that investment in capital was carried in many firms beyond "efficient" levels, due to highly subsidized costs of machinery and equipment. We cannot exclude the possibility, though, that this negative association reflects a lesser efficiency by state enterprises and multinational firms that tend to be more capital intensive.[13] Also, as suggested by Alves (1987), this negative association, also revealed in his study, may arise as a consequence of the barriers to entry represented by high capital intensity.

Although tempting, these explanations should be considered with care, since our measures for the capital input are probably not very precise. In particular, measurement errors will lead to a downward-biased estimate for the association between efficiency and capital intensity, and, consequently, they could be responsible for the negative correlations obtained. Besides that, we see that our results contrast with

13 - See Tyler (1978) and Willmore (1987) for some empirical evidence in that regard.

those of Braga and Rossi (1986), for whom a positive correlation between the two variables emerged in 32 of the 136 sectors in their study.

Capital utilization (CU) was significantly correlated with efficiency for around one-sixth of the sectors -- for one-third of these the correlation showed the wrong sign. These results seem to put in check the precision of our estimates for CU.

In the second row of each part of Table 6, we report the number of significant correlations in 1970 for the reduced sample. The results replicate, broadly speaking, those for the complete sample, although the number of significant correlations falls for every variable, a result that is explained only in part by the smaller number of sectors for which estimates were obtained.

This behavior suggests that part of the significant correlations observed for the complete sample were simultaneous with the SIZE variable -- that is, they reflected differences between small and large firms. This seems to be the case with SIZE itself and also CI.

In Table 7, we report the distribution of correlations in 1970, when the frontier is obtained without imposing constant returns to scale (restrictions (3) and (4)). The most interesting difference from the results obtained before seems to be the smaller number of sectors with positive correlations between efficiency and SHINV. For the other variables, including SIZE, the distribution of correlations changes only marginally.

In the third row of each part of Table 6, we present the number of significant correlations in 1970 when the constant returns to scale restriction is relaxed. Compared to other results three differences are noteworthy. First, the smaller number of sectors where trade orientation is significantly associated with efficiency. Second, although SIZE is less associated with efficiency, as should be expected, in many sectors the correlation is still significant. Third, in this case the number of significant correlations for capital intensity declines only marginally. The same happens to the ratio of investment to capital.

In the second last row of each part of Table 6, we have the number of significant correlations in 1980 for the complete sample. The first interesting observation is that for 1980 the share of exports in output was positively and significantly associated with efficiency for 31 sectors. This is rather impressive, given that on average only 5.3% of total manufacturing output was directly exported by the establishments in that year.

Results are not so remarkable for SHIMI -- with six of the thirteen significant correlations presenting the wrong sign -- or for ROY, for which we obtained similar results, whereas, once more, results point to a relevant impact of SHINV on efficiency. For SHIMI it is probable that the lack of expressive results is a consequence of the limited use of directly imported material inputs.[14]

The correlations for MP seem to support Kendrick and Grossman's enlightenment hypothesis in various sectors and are consistent with those derived for sector averages (Pinheiro (1989)). Results for the skill composition of the labor force are once more mixed, with half the significant correlations having the wrong sign.

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14 - In 1980, imports accounted for a very small fraction of the consumption of material inputs outside the oil refining sector.

TABLE 7

DISTRIBUTION OF CORRELATION COEFFICIENTS - 1970
Relaxing The Constant-Returns-to-Scale Restriction
(Complete Sample, Number of Employees >5)

	SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
<-0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.7/-0.4	0	3	0	1	1	0	0	1	3	0	2	0	0
-0.4/-0.2	0	1	5	2	2	0	0	2	6	0	33	4	0
-0.2/-0.1	10	5	6	2	7	10	0	6	10	0	41	4	0
-0.1/0.0	50	17	35	63	32	49	1	23	37	4	22	31	0
<0.0	60	26	46	68	42	59	1	32	56	4	98	39	0
0.0/0.1	30	15	30	28	45	33	6	55	35	54	3	51	0
0.1/0.2	10	7	14	4	12	4	25	11	7	33	0	9	0
0.2/0.4	1	10	7	1	2	5	59	3	2	10	0	1	4
0.4/0.7	0	4	2	0	0	0	10	0	0	0	0	0	42
>0.7	0	2	0	0	0	0	0	0	0	0	0	0	55
>0.0	41	38	53	33	59	42	100	69	44	97	3	61	101
TOTAL	101	64	99	101	101	101	101	101	100	101	101	100	101

Note: See text for description of variables.

TABLE 8

DISTRIBUTION OF CORRELATION COEFFICIENTS - 1970
Correlations for 30 Largest Sectors

		SHDEX	SHIMI	SHINV	ROY	MP	SW	RRM	ILM	CCS	SIZE	CI	CU	PROF
	1970	3	0	0	3	6	4	0	0	1	0	25	1	0
<0.0	1980	0	5	0	2	3	5	0	1	0	0	25	0	0
	1970	3	5	8	0	1	1	27	9	0	22	0	5	30
>0.0	1980	12	3	3	1	8	1	26	10	1	23	0	1	27
	1970	6	5	8	3	7	5	27	9	1	22	25	6	30
TOTAL	1980	12	8	3	3	11	6	26	11	1	23	25	1	27

Note: See text for description of variables.

In 1980, the correlations between efficiency and both the rate of return and profitability showed to be also positive and significant. For about one-quarter of the sectors we observe a significant correlation between efficiency and the ratio of investment to the stock of capital (ILM), almost all positive. On the other hand, CCS does not seem to have been significantly associated with efficiency, at least not in a definite direction. As for CU, results are similar to those derived for 1970.

SIZE and efficiency were positively and significantly correlated for 80% of the sectors, once more revealing a positive role for scale in the absorption and/or efficient use of new technology. On the other hand, for 89 of the 104 sectors examined a negative and significant association was obtained between capital intensity and efficiency.

The sign distribution of significant correlations for the reduced sample in 1980 -- reported in the last row of each part of Table 6 -- supports the idea that part of the associations obtained for the complete sample are due to firms' size. This seems to be the case with exports, male participation, capital intensity and the investment-capital ratio. Nonetheless, it is noteworthy that several sectors presented a significant and positive association between SIZE and efficiency even for the reduced sample.

In Table 8, we examine the sign of significant correlations for the thirty largest sectors of Brazilian manufacturing. Results are very similar to those observed in Table 6 for all sectors. Exports are more frequently associated with efficiency in a significant way in 1980 than in 1970 -four times as much, to be precise- whereas the opposite picture is unveiled for SHINV.

SIZE is a relevant explanation of differences in efficiency in 1970 and in 1980, while a negative association for capital intensity is common in both years. For 1970 and 1980 significant and positive associations result for the rates of return and profitability. Results for MP and SW are as mixed for the main sectors as for all of the manufacturing industry. Finally, the composition of the stock of capital and of investment, the ratio of royalties to output and the degree of capital utilization are significantly associated with efficiency in few of the largest sectors and not in a systematic fashion.

5) Final Remarks

In this paper we used data at establishment level to estimate frontier production functions for each sector of Brazilian manufacturing in 1970 and 1980. We used these, afterwards, to correlate a set of thirteen variables with the level of efficiency at establishment level.

In 1970, the main impact of trade on efficiency seems to have arisen from the use of imported capital goods in investment -- for one-fifth of the sectors a positive association with efficiency was revealed. For 1980 this variable was significantly related with efficiency for one-sixth of the sectors considered. In 1970 and 1980 imports of material inputs seem to have had little impact on efficiency at establishment level. This may be in part due to the fact that only imports directly accomplished by the establishment were reported in the censuses.

For exports, in 1970, only a sixth of the sectors presented significant correlations, and of those one-third had the "wrong" sign. Quite a different picture was unveiled for 1980. Export shares and efficiency were significantly correlated for 31 sectors -- roughly one-third of the cases considered -- in all cases positively. Furthermore, for 40% of the thirty largest sectors a positive and significant correlation was obtained in 1980 between efficiency and exports.

Establishment SIZE was found to be positively and significantly correlated with efficiency for about 80% of the sectors in 1970 and 1980. To a certain extent this reflects the importance of economies of scale -- when the reduced sample of larger firms was used, or the assumption of constant returns to scale relaxed (for 1970), the number of significant correlations declined considerably. Nevertheless, other factors, such

as better and more enlightened management, large market shares, and so on, may also be reflecting in efficiency levels through the size variable.

Newer capital vintage composition was found to have had a positive and significant impact on efficiency for 16 sectors in 1970 and 24 in 1980. Besides that, efficient establishments were found to be more profitable and to have had a higher rate of return on their capital stocks.

In both 1970 and 1980 a large number of sectors presented negative and significant correlations between efficiency and capital intensity. This association seems to be simultaneous with SIZE -- when the sample of large firms is used the number of significant correlations drops to less than a third of its original value. Interestingly enough, however, the number of sectors with significant associations declines only marginally when the assumption of constant returns to scale is relaxed. Nonetheless, as many of these negative correlations can probably be credited to measurement errors, solid conclusions will have to wait for further research.

Our analysis of significant correlations in the largest 30 sectors of Brazilian manufacturing industry revealed little more than we already knew -- results for these sectors tended to parallel those obtained for the whole of the manufacturing industry. As for the differences between 1970 and 1980, the two most noteworthy facts are the increased frequency of significant correlations for exports and the smaller number of significant associations for imports of machinery.

Although only tentative and hampered by measurement errors, our results can be used to make some suggestions with respect to the Brazilian industrial policy of the 1990's. First, the country should search for competitive pressures abroad, especially through exports, rather than only through the division of her limited domestic market among many small firms. Second, the foreign exchange obtained from exports should be used to expand the used of imported material inputs and machinery and equipment to enhance the absorption of modern technology.

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