# "Total Factor Productivity Growth, Technical Progress, and Technical Efficiency Change in the Brazilian Industry in 1996-2000: A Firm-level DEA Approach".

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## Abstract

Production efficiency and technical progress are crucial elements in analyzing industries' international competitiveness and growth trends. One way to assess competitiveness of countries or economic sectors within them considers the tendency of their unit costs of production to decline, which is expressed by positive growth rates of their Total Factor Productivity (TFP). A methodology developed by FÄRE et al. (1994), and derived from the Data Envelopment Analysis (DEA) approach, allows for the estimation of TFP growth rates and its components, technical efficiency, technical change, and scale changes. We use a firm-level Industrial Census panel data to apply this methodology to compute TFP growth rates for 27 Brazilian Industries in 1996-2000. Our results show negative annual average TFP growth rates in 1996-2000 for almost three quarters of the sectors analyzed with an average decline of 2.9%. When we consider the periods 1996-1998 and 1998-2000, prior and posterior to the change in the exchange-rate regime from pegging the real to the dollar to letting it float, figures show a reversal from an average growth rate of 2.9% in the first period to an average decline of 8.1% in the second one.

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## 1. Introduction

There was a lively debate in the first five years of the 1990s about trends in productivity in the Brazilian economy. Although there was, in general, agreement among analysts with respect to the evidence that the economy had achieved in the 1990s higher levels of TFP growth rates than in the 1980s, the discussion about the reasons for that performance offered a more diversified range of opinions. Many analysts tended to associate the performance of the TFP growth rates in Brazil with the deepening in the degree of the economy openness and, conditional on the intensity of the analyst support for that commercial policy, the welfare analysis would emphasize productivity gains or loss of jobs. We now benefit from the possibility of scrutinizing data from the second half of the 1990s with the advantage of having more time to put the analysis of the first half of the last decade in a better perspective. This work computes a new round of TFP growth rates for sectors in the mining and in the manufacturing divisions of the Brazilian economy using Industrial Census firm-level panel data from the period 1996-2000, and offers a new basis for the endless quest for rationales for the observed productivity performance. The idea behind TFP is traced back to the seminal work of Solow (1957), who proposes a technical progress interpretation to the product growth component unexplainable by factor accumulation. Whereas this approach to the question of productivity is concerned with macroeconomic aggregates, Farrel (1957) tackles the issue from a microeconomic viewpoint allowing the measurement of productivity to include both technical and allocative inefficiencies, which are measured given relative prices and an estimated production frontier. The main methods of estimating frontier production functions are the Data Envelopment Analysis (DEA), which is based on linear programming techniques, and the Stochastic Frontier Approach (SFA), which uses econometric methods. This paper uses the DEA methodology following the approach proposed by Färe et al. (1994) in order to estimate TFP and its components for each of the 27 sectors of the Brazilian industry in the second half of the nineties. The identification of the components technical efficiency, scale change and technical change allow us to determine which of them is more influential on the observed TPF's variations in the sectors analyzed. The work has four Sections - including this Introduction - organized as follows: Section 2 presents a summary of the DEA approach to the questions of productivity and technical efficiency, Section 3 describes the firm-level panel data utilized in the empirical work and discusses its main results, and Section 4 concludes the paper.

## 2. Total Factor Productivity, Efficiency, and Data Envelopment Analysis

In 1957 Farrel proposes an efficiency measure that considers overall efficiency as having two components, allocative efficiency and technical efficiency. Allocative efficiency (or price efficiency) reflects the ability of a firm to use inputs in optimal proportions given a set of prices , whereas technical efficiency relates to the ability of a firm to attain maximal output given a set of inputs (quantities). Farrel's approach spanned a diverse body of both theoretical and empirical literature, as well as refinement proposals to assess technical efficiency and productivity. A good example is the work of Färe et al (1994), who restate the Malmquist index in order to propose a measure of productivity growth identifying related components.[1] The component distance functions of the Malmquist index are calculated through non-parametric programming methods (data envelopment analysis - DEA). The methodology "adjusts" a production frontier under the assumption of constant returns to scale for each time period and identifies, for any decision making unit (DMU) and every couple of years, both "catching-up" ("shift-away") movements towards (away from) the "best-practice" (frontier) and shifts of the frontier itself – the technical change component. [2] The total factor productivity change is the product of these two components. On the other hand, maintaining the hypothesis of variable returns to scale Färe et al (1994) consider a further decomposition of TFP that refines their concept of technical efficiency change into pure technical efficiency change and scale efficiency change. The technical efficiency change index, constructed under the hypothesis of a variable returns to scale frontier, relates to the pure technical efficiency change, computed under the assumption of a constant returns to scale frontier, by means of the scale efficiency change, which is defined to make the product of the latter two indices equal to the first one.

In order to define the Malmquist index of productivity change we consider, for each time period $t = 1, \ldots, T$, a production technology $\mathbf{S}^t$:

$\mathbf{S}^t=\{(\mathbf{x}^t,\mathbf{y}^t): \mathbf{x}^t \text{ can produce } \mathbf{y}^t\}$[3]

Given the production technology at time $t$, the output distance function is defined at $t$ as:

$D^t_o(\mathbf{x}^t, \mathbf{y}^t) = \inf\{\theta : (\mathbf{x}^t, \mathbf{y}^t/\theta) \in \mathbf{S}^t\}$[4]

This distance function is defined as the inverse of Farrel's (1957) technical efficiency measure:

$$D^t_o(\mathbf{x}^t, \mathbf{y}^t) = \inf\{\theta : (\mathbf{x}^t, \mathbf{y}^t/\theta) \in \mathbf{S}^t\} = (\sup\{\theta : (\mathbf{x}^t,\theta\mathbf{y}^t) \in \mathbf{S}^t\})^{-1}$$

This function returns the minimum value by which the output may be divided and still be in the production set whose frontier is defined by technology $\mathbf{S}^t$. Since $\theta \leq 1$, scaling back the output by the least possible factor gives maximum proportional expansion of the output vector $\mathbf{y}^t$, given inputs $\mathbf{x}^t$ and technology $\mathbf{S}^t$.
Analogously, the following distance functions may be defined:

[1] Caves et al. (1982) brings the Malmquist index to the total factor productivity literature. . The distance to the frontier may be defined either as a vertical distance, or as a horizontal distance, or even as a combination of both.
[2] Decision making unit (DMU) is a catch-all taxonomy that, depending on the available data set, may describe firms, non-profit organizations, countries, etc. Färe et al. (1994) apply the DEA Malmquist methodology to a sample of OECD countries, which are therefore their DMUs; the industrial census data considered here have firms as DMUs.
[3] Färe et al (1994) assume that $S^t$ satisfies the following axioms: monotonicity, convexity and ray unboundness. More on these axioms on Färe (1988).
[4] The subscript 'o' is used to indicate that the distance function is being defined from the output point of view, i.e., the vertical distance from the frontier.

$D^{t}_{o}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) = \inf\{\theta : (\mathbf{x}^{t+1}, \mathbf{y}^{t+1}/\theta) \in \mathbf{S}^{t}\}$
$D^{t+1}_{o}(\mathbf{x}^{t}, \mathbf{y}^{t}) = \inf\{\theta : (\mathbf{x}^{t}, \mathbf{y}^{t}/\theta) \in \mathbf{S}^{t+1}\}$
$D^{t+1}_{o}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) = \inf\{\theta : (\mathbf{x}^{t+1}, \mathbf{y}^{t+1}/\theta) \in \mathbf{S}^{t+1}\}$

These expressions are all distance functions with straightforward interpretations. For example, the first expression measures the maximal proportional expansion of the output vector $\mathbf{y}^{t+1}$ required to make $(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$ feasible when the technology of the time period *t* is used.

Caves et al. (1982) define the Malmquist productivity index based on the technology of period *t* as:

$M^{t}_{CCD} = D^{t}_{o}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) / D^{t}_{o}(\mathbf{x}^{t}, \mathbf{y}^{t})$

An alternative specification uses the technology of period *t*+1 as a basis to define the index:

$M^{t+1}_{CCD} = D^{t+1}_{o}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) / D^{t+1}_{o}(\mathbf{x}^{t}, \mathbf{y}^{t})$

Ray and Desli (1997) argue that the Malmquist index will always be correctly measured by the ratio distance functions under the assumption of a constant returns to scale technology even when the “true” technology is not characterized by constant returns to scale.[5]

To avoid an arbitrary benchmark,[6] Färe et al (1994) define the output-based Malmquist productivity change index as the geometric mean of these two Malmquist indices, i.e.:

$M_{o}(x^{t+1}, y^{t+1}, x^{t}, y^{t}) = (M^{t}_{CCD} \mathrm{X}\ M^{t+1}_{CCD})^{1/2}$

The expression specifies the productivity index as composite of the maximum feasible output expansion in time *t+1*, given $\mathbf{x}^{t+1}$ and technology at time *t*, and the maximum feasible output expansion in time *t*, given $\mathbf{x}^{t}$ and technology at time *t+1*.

An equivalent way of writing this index would be:

$$M_{o}\left(x^{t+1}, y^{t+1}, x^{t}, y^{t}\right) = \frac{D_{o}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{o}^{t}\left(x^{t}, y^{t}\right)}\left[\left(\frac{D_{o}^{t}\left(x^{t+1}, y^{t+1}\right)}{D_{o}^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right)\left(\frac{D_{o}^{t}\left(x^{t}, y^{t}\right)}{D_{o}^{t+1}\left(x^{t}, y^{t}\right)}\right)\right]^{1/2}$$

The technical efficiency change (EFFCH) component is:

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5 Balk (1998) states that a lower bound to the Malmquist output index (MOI), defined using the technology of period *t*, is a Laspeyers quantity index whereas an upper bound to the MOI, constructed employing the technology of time *t+1*, is the Paasche index. The Fischer’s Ideal index, which is the geometric mean of the Paasche and Laspeyres indices, is an approximation of the Malmquist index.

6 According to Moorsten (1961) results are not neutral with respect to the choice of the time period to be used as a basis.

$$\frac{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_o^t\left(x^t, y^t\right)}$$

The technical change component (TECHCH) is:

$$\left[\left(\frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right)\left(\frac{D_o^t\left(x^t, y^t\right)}{D_o^{t+1}\left(x^t, y^t\right)}\right)\right]^{1/2}$$

Maintaining the hypothesis of variable returns to scale technology, the technical efficiency change index may be further decomposed into two components, the pure technical efficiency change and the scale efficiency change.

The pure technical efficiency change (PEFFCH) is defined as:[7]

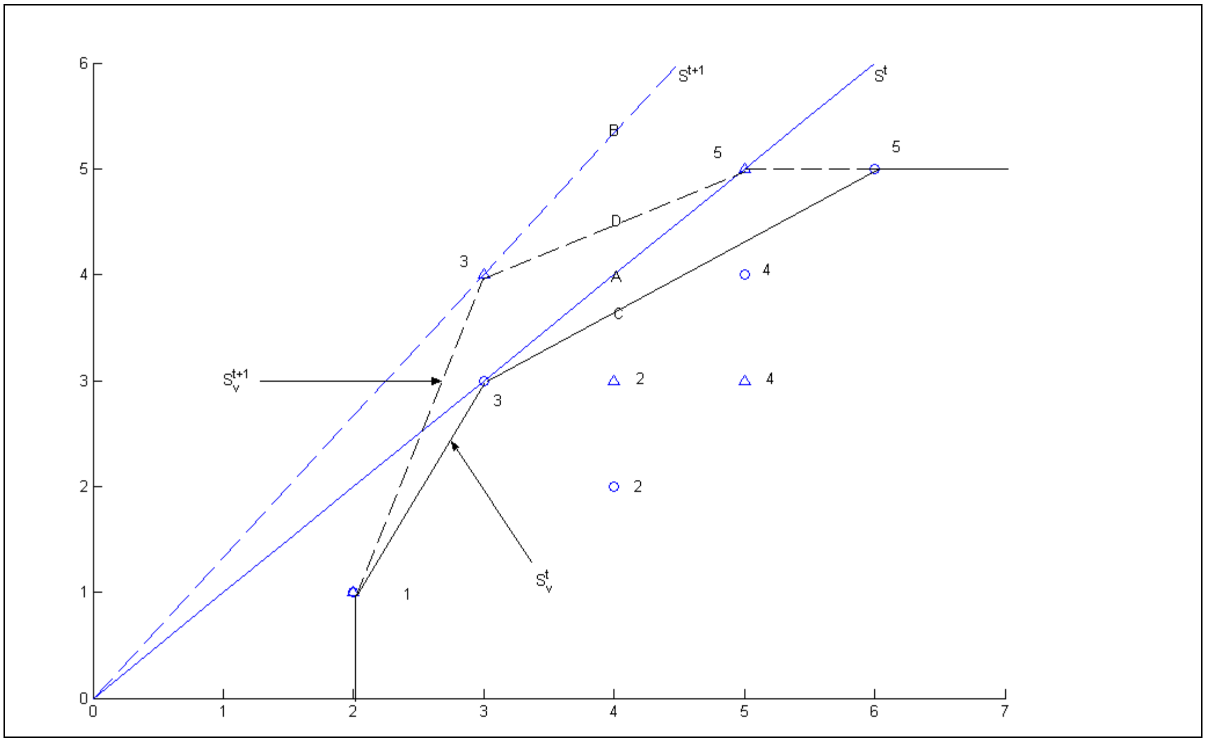
$$\frac{D_{oV}{}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{oV}{}^{t}\left(x^t, y^t\right)}$$

The scale efficiency change (SCH)is expressed as:[8]

$$\frac{D_o{}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{oV}{}^{t+1}\left(x^{t+1}, y^{t+1}\right)} \div \frac{D_o{}^{t}\left(x^t, y^t\right)}{D_{oV}{}^{t}\left(x^t, y^t\right)}$$

Figure 1

[7] The 'v' subscript indicates that the distance function is calculated under the assumption of variable returns to scale technology.
[8] Note that EFFCH=PEFFCH X SCH.




Färe et al.'s (1994) computes the Malmquist productivity index using non-parametric programming techniques. Given K firms, N inputs, M products and T periods of time, their reference technology in period *t* under constant returns to scale is estimated as:[9]

$$S^t = \{(x^t, y^t): y_m^t \leq \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \quad \forall \ m = 1, \ldots, M;$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq x_n^t \quad \forall \ n = 1, \ldots, N;$$

$$\sum_{k=1}^{K} z^{k,t} \geq 0 \quad \forall \ k = 1, \ldots, K\}$$

where $z^{k,t}$ is a variable associated with the production intensity of a particular firm activity and $y_m$ indicates the output m of the vector of outputs **y**.

The reference technology of period *t* is the set of all pairs ($\mathbf{x}^t$, $\mathbf{y}^t$) for which: 1) each output ($\mathbf{y}^{k,t}$) does not exceed the 'virtual product' defined by $\mathbf{z}_m{}^{k,t} y^{k,t}$; 2) the vector of inputs ($\mathbf{x}^t$) is greater than the 'virtual input' for each input; 3) the weights used to define the virtual output and the virtual inputs are non-negative.

[9] The stated technology exhibits constant returns to scale and strong disposability of inputs and outputs.

By adding the following restriction to the definition of reference technology, the assumption of returns to scale may be relaxed:

$$\sum_{k=1}^{K} z^{k,t} = 1$$

The Malmquist index of each firm k' is computed under the assumption of constant returns to scale technology and involves the following four linear programming problems:

$$\left(D_o^t\left(x^{k',t}, y^{k',t}\right)\right)^{-1} = \max \ \theta^{k'}$$

s.t.

$$\theta^{k'} y_m^{k',t} \le \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \qquad m = 1,\ldots,M$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \le x_n^{k',t} \qquad n = 1,\ldots,N$$

$$z^{k,t} \ge 0 \qquad k = 1,\ldots,K$$

$$\left(D_o^{t+1}\left(x^{k',t+1}, y^{k',t+1}\right)\right)^{-1} = \max \ \theta^{k'}$$

s.t.

$$\theta^{k'} y_m^{k',t+1} \le \sum_{k=1}^{K} z^{k,t+1} y_m^{k,t+1} \qquad m = 1,\ldots,M$$

$$\sum_{k=1}^{K} z^{k,t+1} x_n^{k,t+1} \le x_n^{k',t+1} \qquad n = 1,\ldots,N$$

$$z^{k,t+1} \ge 0 \qquad k = 1,\ldots,K$$

$$\left(D_o^t\left(x^{k',t+1}, y^{k',t+1}\right)\right)^{-1} = \max \ \theta^{k'}$$

s.t.

$$\theta^{k'} y_m^{k',t+1} \leq \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \qquad m = 1,\ldots,M$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq x_n^{k',t+1} \qquad n = 1,\ldots,N$$

$$z^{k,t} \geq 0 \qquad k = 1,\ldots,K$$

$$\left(D_o^{t+1}\left(x^{k',t}, y^{k',t}\right)\right)^{-1} = \max\ \theta^{k'}$$

s.t.

$$\theta^{k'} y_m^{k',t} \leq \sum_{k=1}^{K} z^{k,t+1} y_m^{k,t+1} \qquad m = 1,\ldots,M$$

$$\sum_{k=1}^{K} z^{k,t+1} x_n^{k,t+1} \leq x_n^{k',t} \qquad n = 1,\ldots,N$$

$$z^{k,t+1} \geq 0 \qquad k = 1,\ldots,K$$

The four optimization problems above aim to maximize the k-th firm efficiency statistic $\theta^{k'}$ subject to the constraints that the inputs used by each firm be greater than or equal to the quantity defined as reference ('virtual input') to the particular optimization problem. Two additional constraints state that the weights are non-negative and that the output of each firm, weighted by the efficiency statistic, does not exceed the reference product ('virtual product').

3. 3. **Productivity Indices**

## 3.1. Data description

The work uses firm-level data from the Annual Survey of Mining and Manufacturing Industries[10] (PIA in its Portuguese acronym), conducted by the Brazilian Institute of Geography and Statistics (IBGE). PIA's main objective is to provide a basis for studying the structural characteristics of the Brazilian industries from both a cross-sectional perspective and a time-series viewpoint. PIA's sample includes firms established until December 31st of the year analyzed by the survey having a local corporate taxpayer registration number (CNPJ).[11] We use a panel of 13420 firms over a five years time span, 1996-2000. These firms are distributed among 27 sectors of activities that follow the National Classification of Economic Activities (CNAE-50) - 23 of them are included in the Manufacturing Division and 4 in the Mining Division.

The dataset has sectors with a diverse number of firms included. The range varies from "Extraction of crude petroleum and related services," which encompasses 6 firms, to "Food products and beverages," which consists of 1812 firms - the mean value among the sectors considered is 497. Output Y is defined as the difference between "Sales Net Revenue" and "Raw-materials, auxiliary material and components" (which includes package material, fuel used as raw-material and lubricants). This constructed variable is a proxy for the value added of the firm.[12] Labor input is considered as the annual average of "People employed in the production" because there are no available figures on the total number of hours worked per year. The implicit assumption here is that the average number of hours worked per employee is constant along the years analyzed. The stock of capital is computed using the method of perpetual inventory applied to the data on the firms' flow of investment. The difference between "Acquisition of Machines and Industrial Equipment" and "Machines and Industrial Equipment write-off" is used as a proxy for investment flow. The value of capital used to start the series, $K_j(0)$, is calculated according to a methodology adapted from Young (1995). The author suggests the use of the first five years of investment series as representative of the growth prior to the beginning of the series when there is no availability of long time series data. Thus, for positive depreciation rates:

$$K_j(0) = I_j^0/(g_j + \delta_j)$$

where $I_j^0$ is the first year of investment for asset j, $\delta_j$ is the depreciation rate for asset j, and $g_j$ is the average growth of investment in asset j in the first five years of the investment series. Given the short time span available for the investment series, this work considers $Ij^0$ as the average investment of the period analyzed and uses three different assumptions for

[10] Every firm that has at least 30 employees is enforced by law to answer PIA's survey.
[11] Hence, the informal sector is not encompassed by this survey.
[12] Nominal values are deflated by the corresponding IPA-OG price index. In the case where there is no direct compatibility of the activities, IPA-OG média geral is chosen as the proper deflator. Nominal values are deflated by the corresponding December's deflator. An alternative to this approach would be to suppose that the reported values are simple sum of monthly values and that their distribution is uniform across the year. The results obtained from these approaches did not differ significantly.

the term (gj + δj), 10%, 15% and 20%. The results obtained under these different assumptions are fairly robust, except for the following sectors: “Mining of metal ores”, “Tobacco products”, “Basic Metallurgy” and “Other transport equipment”.

### 3.2. Empirical Results

Table 1 below summarizes some basic statistics total factor productivity and its components, discriminating the results for the whole industry and the manufacturing division.

Table 1
Total factor productivity indices and their components, 1996-2000

| Statistic | Technical Efficiency | | Technical Change | | Pure Technical Efficiency | | Scale Change | | Total Factor Productivity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division |
| Average | 0.974 | 0.967 | 1.026 | 1.027 | 0.977 | 0.975 | 0.996 | 0.991 | 0.984 | 0.975 |
| Weighted Average* | 0.980 | 0.977 | 1.013 | 1.015 | 0.981 | 0.980 | 0.998 | 0.996 | 0.971 | 0.969 |
| Maximum | 1.217 | 1.217 | 1.351 | 1.351 | 1.141 | 1.141 | 1.192 | 1.192 | 1.108 | 1.058 |
| Minimum | 0.731 | 0.731 | 0.791 | 0.791 | 0.797 | 0.797 | 0.803 | 0.803 | 0.919 | 0.919 |
| Standard Deviation | 0.123 | 0.130 | 0.140 | 0.146 | 0.080 | 0.086 | 0.089 | 0.094 | 0.041 | 0.032 |
| Coefficient of Variation | 0.127 | 0.134 | 0.137 | 0.142 | 0.082 | 0.088 | 0.089 | 0.095 | 0.041 | 0.032 |

*The weights were defined as the sector’s VAM participation on total VAM.

The first row in Table 1 shows the simple average computed considering the indices of the 27 sectors included in the data base, the second entry presents a weighed average l in which the weights are the sectors’ participation in the total Value Added by Manufacture (VAM) as indicated in the lower part of table 1.[13] The simple average Industry TFP index records a yearly negative growth rate of 1.6% in 1996-2000 while the weighed average shows a yearly decline of 2.9%. The correspondent figures to the Manufacturing Division are 2.5% and 3.1%, respectively. It is worth noting that every coefficient of variation computes for the Manufacturing Division is greater than the correspondent for the Whole industry, indicating a greater relative dispersion in the former industry.

Among the TFP components, technical efficiency shows the worst average performance and scale change has the second worst record. Although technical change shows an average yearly growth rate of 1.3% it records also the greatest coefficient of variation, 0.137. The sector “Mining of mineral coal” presents the highest yearly growth rate, 10.8%, whereas “Editing, printing and reproduction of records” shows the poorest performance, an annual negative growth rate of 8.1%.

[13] The following tables would also show both types of computed averages, but henceforth only the weighted one will be commented in the text. Value added by manufacture (VAM) is calculated, in the enterprise level, as the difference between the gross value of industrial production and the cost of industrial operations.

Table 2 below identifies the main component responsible for the registered variation of TFP, discriminating the direction of such variation, i.e., the proportion of sectors for which the component is the key factor for the observed performance.

Table 2
Main component responsible for TFP's evolution,1996-2000.

| Main Component | Total Factor Productivity | | | | Total | |
|---|---|---|---|---|---|---|
| | TFP Increase | | TFP Decrease | | | |
| | Whole Industry | Manufacturing Division | Whole Industry | Manufacturing Division | Whole Industry | Manufacturing Division |
| Technical change | 7.4% | 4.3% | 29.6% | 30.4% | 37.0% | 34.8 |
| Pure efficiency change | 3.7% | 4.3% | 25.9% | 26.1% | 29.6% | 30.4 |
| Scale change | 14.8% | 13.0% | 18.5% | 21.7% | 33.3% | 34.8 |
| *Total* | *25.9%* | *21.7%* | *74.1%* | *78.3%* | *100%* | *100%* |

Almost three quarters of the sectors analyzed records a decrease in their TFP rates in 1996-2000. Scale change is the main component behind the performance of sectors with positive TFP growth rates, 14.8%; that means, in 57% of the cases (14.8% out of 25.9%) the sectors recording positive TPF growth rates have scale change as the key factor behind the performance. In contrast, technical change is the component responsible for the performance of the sectors recording negative TFP growth rates in 40% of the cases (29.6% out of 74.1%).

Considering both the Manufacturing Division and the Whole Industry, the latter one has a greater percentage of sectors showing a decrease in TFP rates in 1996-2000, 78.3%, than the former; again scale change and technical change are the main components influencing TFP.. In both groups the sectors presenting TFP negative growth rates have technical change as the key factor bringing about the observed outcome, whereas the sectors showing positive growth rates have scale change as the main component responsible for their performance. The five years analyzed includes the year of the exchange rate regime change, which occurred in January 1999. It is interesting to check if there is some hint of structural change in the TFP pattern, associated with this exchange rate regime change, by taking a look at two sub-periods, 1996-1998 and 1998-2000. It is worth mentioning that, in general, 1998-2000 has a higher exchange rate depreciation trend than 1996-1998, which means more pricey imported inputs. The detachment between the cost of imported and domestic inputs in 1998-2000 makes some few sectors more difficult to compare with others, one example is "Chemical Products," which is more dependent on imported inputs than most of the other sectors in the economy. Tables 3 and 4 below present TFP growth rates and their components for the sub-periods mentioned.

Table 3
TFP indices and its components' evolution, 1996-1998

| Sub-Period | Technical Efficiency | | Technical Change | | Pure Technical Efficiency | | Scale Change | | Total Factor Productivity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division |
| 1996-1997 | 1.124 | 1.147 | 0.993 | 0.948 | 1.073 | 1.100 | 1.051 | 1.047 | 1.029 | 1.002 |
| 1997-1998 | 0.993 | 0.976 | 1.113 | 1.127 | 0.973 | 0.947 | 1.028 | 1.037 | 1.052 | 1.041 |
| *Average* | *1.056* | *1.058* | *1.051* | *1.034* | *1.022* | *1.021* | *1.039* | *1.042* | *1.040* | *1.021* |
| 1996-1997* | 1.273 | 1.279 | 0.871 | 0.867 | 1.179 | 1.185 | 1.086 | 1.085 | 1.024 | 1.024 |
| 1997-1998* | 1.037 | 1.033 | 1.064 | 1.068 | 0.950 | 0.945 | 1.106 | 1.107 | 1.034 | 1.032 |
| *Weighted Average** | *1.149* | *1.149* | *0.963* | *0.962* | *1.058* | *1.058* | *1.096* | *1.096* | *1.029* | *1.028* |

*The weights were defined as the sector's VAM participation on total VAM.

The sub-period 1996-1998 presents an average increase of TFP index for the Whole Industry and the Manufacturing Division, 2.9% and 2.8%, respectively (Table 3), whereas the correspondent figures for 1998-2000 are average decreases of 8.1% and 9.6% (Table 4). The key component of the positive performance in 1996-1998 is technical efficiency; by decomposing technical efficiency into pure technical efficiency and scale change, it becomes evident that the major factor explaining the TFP evolution in 1996-1998 is scale change, which reports an annual average increase of 9.6% (Table 3). The most important factor bringing about the poor performance of the TFP indices in 1998-2000 is pure technical efficiency (Table 4). Only 6 out of 27 sectors show negative TFP changes in 1996-1998, "Leather tanning, manufacturing of leather and travel products, and footwear"; "Rubber and Plastic articles"; "Metal products – except machines and equipment"; "Electronic material and communication equipment," "Furniture and various industries"; and "Recycling;" in contrast, only 2 sectors present positive TFP changes in 1998-2000, "Tobacco products" and "Wood products."

Table 4
TFP's and its components' evolution, 1998-2000

| Sub-Period | Technical Efficiency | | Technical Change | | Pure Technical Efficiency | | Scale Change | | Total Factor Productivity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division | Whole Industry | Manuf. Division |
| 1996-1997 | 0,968 | 0,974 | 0,992 | 1,001 | 0,973 | 0,977 | 0,998 | 1,000 | 0,877 | 0,877 |
| 1997-1998 | 0,999 | 0,986 | 1,236 | 1,285 | 0,965 | 0,957 | 1,006 | 0,996 | 1,001 | 1,000 |
| *Average* | *0,983* | *0,980* | *1,107* | *1.134* | *0.969* | *0,967* | *1.002* | *0,998* | *0,937* | *0,937* |
| 1996-1997* | 0,885 | 0,853 | 1,035 | 1,007 | 0,913 | 0,882 | 0,984 | 0,951 | 0,865 | 0,836 |
| 1997-1998* | 0,974 | 0,965 | 1,319 | 1,347 | 0,967 | 0,963 | 0,970 | 0,961 | 0,977 | 0,979 |
| *Weighted Average** | *0,929* | *0,907* | *1,168* | *1,164* | *0,939* | *0,922* | *0,977* | *0,956* | *0,919* | *0,904* |

*The weights were defined as the sector's VAM participation on total VAM.

The Tables which follow present a full account of the results for selected sectors among the ones included in the data-base. These sectors are worth examining because of: 1) their performance 2) the number of firms in it; 3) their relevance for industry or short term business analysis.

Table 5
Total Factor Productivity and its components
Mining of mineral coal

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 0.880 | 1.788 | 0.905 | 0.972 | 1.573 |
| 1997-1998 | 0.940 | 1.083 | 1.035 | 0.908 | 1.018 |
| 1998-1999 | 0.859 | 0.960 | 0.928 | 0.926 | 0.825 |
| 1999-2000 | 1.032 | 1.107 | 0.992 | 1.041 | 1.143 |
| *Average* | *0.925* | *1.198* | *0.964* | *0.960* | *1.108* |

Table 5 above presents TFP figures relative to "Mining of mineral coal," which records the largest average annual TFP growth rate, 10.8%. Technical change is the main responsible for this performance. This result, combined with values below unity reported for both indices of pure technical efficiency and scale efficiency, implies that technical change is probably concentrated on a small subset of firms. This scenario suggests a frontier expansion[14] and a greater dispersion in terms of efficiency. It is worth noting that 1998-1999 was the sole sub-period in which this sector's TFP worsened. In 1998-1999 none of the indices assumed a value greater than the unity. Positive variations for pure technical efficiency and scale change are observed in 1997-1998 and in 1999-2000, respectively.

Table 6 below shows the TFP numbers relative to "Electrical machinery, apparatus and material".

Table 6
Total factor productivity and its components
Electrical machinery, apparatus and material

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.023 | 1.056 | 0.771 | 1.327 | 1.081 |
| 1997-1998 | 1.108 | 0.943 | 0.797 | 1.391 | 1.045 |
| 1998-1999 | 0.734 | 1.173 | 0.865 | 0.849 | 0.862 |
| 1999-2000 | 1.598 | 0.701 | 1.238 | 1.291 | 1.120 |
| *Average* | *1.074* | *0.951* | *0.901* | *1.192* | *1.022* |

[14] It should be noted that, strictly, a technical change index greater than unity is indicative of a growth in the maximal average product.

The sector records an average annual TFP growth of 2.2% having the scale change index as the main component in delivering the outcome with an average annual growth of 19.2%, the highest among all sectors. This performance could have been better if the decrease in TFP had not been so intense during the sub-period 1998-1999. The figures suggest gains in terms of technical change in 1998-1999, but these gains are probably concentrated in a small subset of firms since both the indices of pure technical efficiency and scale efficiency present a reduction of 15% each. With respect to the index of pure technical efficiency, the results indicate an increase in the dispersion in the distribution of firms around the best-practice during the first three sub-periods, but there is a reversal of the situation in 1999-2000. Analyzing the average performance in 1996-2000, it becomes evident that the negative performance attributed to the technical change index could be interpreted as a contraction of the best-practice frontier and that there is a decline in terms of pure technical efficiency; however, the period records a strong growth of the scale change index. This last result is the main determinant of TFP improvement.

Table 7
Total factor productivity and its components
Editing, printing and reproduction of records

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.521 | 0.649 | 1.382 | 1.101 | 0.987 |
| 1997-1998 | 0.977 | 1.043 | 0.983 | 0.994 | 1.019 |
| 1998-1999 | 0.946 | 0.813 | 0.980 | 0.965 | 0.769 |
| 1999-2000 | 0.863 | 1.067 | 0.896 | 0.963 | 0.921 |
| *Average* | *1.049* | *0.875* | *1.045* | *1.004* | *0.919* |

Table 7 above reproduces the TFP statistics relative to "Editing, printing and reproduction of records": the main responsible for the negative performance, the third worst among all the sectors analyzed, is the component technical change, which records a negative variation in 2 out of 4 sub-periods reported. This sector has all indices presenting a negative performance in 1998-1999; it is worth noting that, although both pure technical efficiency and scale efficiency show an average positive growth rate in 1996-2000, these indices remain below unity in the last three sub-periods.

Table 8
Total factor productivity and its components
Metal products – except machines and equipment

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.334 | 0.765 | 1.281 | 1.042 | 1.021 |
| 1997-1998 | 0.966 | 0.993 | 0.937 | 1.031 | 0.959 |
| 1998-1999 | 0.719 | 1.125 | 0.963 | 0.746 | 0.809 |
| 1999-2000 | 1.137 | 0.868 | 1.051 | 1.082 | 0.987 |
| *Average* | *1.013* | *0.928* | *1.050* | *0.965* | *0.940* |

Table 8 above shows the TFP figures of "Metal products – except machines and equipment". The sector experiments a decrease in its TFP index in 1996-2000 mostly because of the performance of the technical change and scale change indices. It is worth noting, TFP index records its lowest value in 1998-1999, scale change is the greatest responsible for such outcome. The only sub-period that reports a positive TFP growth rate is 1996-1997, which is positively influenced by the good performance of the pure technical efficiency index. The 1996-2000 averages suggest a contraction of the best-practice frontier in the period, an increase in the dispersion among firms in terms of their scale efficiency and a decrease in their dispersion in terms of pure technical efficiency. These effects combined yield an average TFP annual decrease of 6%.

Table 9
Total factor productivity and its components
Leather tanning, manufacturing of leather and travel products, and footwear

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 0.791 | 1.247 | 1.064 | 0.743 | 0.985 |
| 1997-1998 | 0.903 | 1.107 | 0.797 | 1.132 | 0.999 |
| 1998-1999 | 1.266 | 0.684 | 1.119 | 1.131 | 0.866 |
| 1999-2000 | 0.495 | 1.890 | 0.661 | 0.748 | 0.935 |
| *Average* | *0.818* | *1.156* | *0.890* | *0.919* | *0.945* |

Table 9 above shows the TFP numbers of "Leather tanning, manufacturing of leather and travel products, and footwear." The technical change index records an average growth rate of 15.6%, not sufficient to make up for the poor performance of the other indices, which all combine for a 5.5% average annual TFP decrease in 1996-2000. This sector, shows the TFP index consistently below unity in all sub-periods. The scale change index is the most important factor driving the TFP performance. Again, these figures seem to suggest a scenario of best-practice frontier expansion in which only a small part of the firms make the move ahead while the technical efficiency difference in levels among them increases.

Table 10
Total factor productivity and its components
Food products and beverages

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.054 | 0.962 | 0.911 | 1.157 | 1.013 |
| 1997-1998 | 0.859 | 1.218 | 1.021 | 0.841 | 1.046 |
| 1998-1999 | 0.763 | 1.109 | 0.632 | 1.207 | 0.846 |
| 1999-2000 | 1.305 | 0.714 | 1.205 | 1.082 | 0.931 |
| *Average* | *0.974* | *0.981* | *0.917* | *1.062* | *0.956* |

Table 10 above reports the TFP performance of "Food products and beverages," which records an average annual decrease TFP of 4.4% in 1996-2000. was Pure technical efficiency, which reports an average annual decrease of 8.3%, is the main responsible for this performance. The figures show also a contraction of the production frontier - an average decrease in technical change - and an average increase in the scale change index.

Considering just the sub-period 1996-1998, the average annual TFP positive change is 2.9%, due mainly to an average expansion of the production frontier of 8.2%. In contrast, the sub-period 1998-2000 presents an average annual negative variation of 11%, the second worst performance among all sectors, heavily influenced by the negative performance of the pure technical efficiency. .

Table 11
Total factor productivity and its components
Textile products

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.385 | 0.694 | 1.252 | 1.106 | 0.962 |
| 1997-1998 | 0.862 | 1.230 | 0.987 | 0.873 | 1.060 |
| 1998-1999 | 0.466 | 1.730 | 0.764 | 0.610 | 0.806 |
| 1999-2000 | 2.082 | 0.470 | 1.040 | 2.001 | 0.978 |
| *Average* | *1.038* | *0.913* | *0.996* | *1.042* | *0.947* |

"Textile products" shows an average TFP decrease comparable to the one presented by "Food products and beverages" 5.3% for the former against 4.4% for the latter. This outcome ranks in the twenty-fourth position among all 27 sectors analyzed. The negative performance is due to the average annual decrease of 8.7% in the index of technical change, which prevails over the average annual increase of 4.2%, shown by the scale change index. Again, the figures show also a contraction of the production frontier - an average decrease in technical change. The sector performance presents an average negative TFP change of 11.2% in 1998-2000 ranking in the twenty-fifth position among the sectors investigated.

Table 12
Total factor productivity and its components
Machines and Equipment

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.654 | 0.668 | 1.543 | 1.072 | 1.104 |
| 1997-1998 | 0.546 | 1.821 | 0.616 | 0.886 | 0.994 |
| 1998-1999 | 1.030 | 0.814 | 1.418 | 0.726 | 0.838 |
| 1999-2000 | 1.979 | 0.510 | 1.199 | 1.651 | 1.009 |
| *Average* | *1.165* | *0.843* | *1.128* | *1.033* | *0.982* |

Table 12 above presents the results of "Machines and Equipment". The average negative TFP change of 1.8% reflects the contraction of 15.7% of the "best practice" production frontier (technical change index), which goes in the opposite way with respect to the positive directions of change observed for scale change and pure technical efficiency, 3.3% and 12.8%, respectively. The last number puts that index in the second position in the ranking of average sector performance of the pure technical efficiency index of the sectors analyzed. Contraction of the production frontier, as measured by the technical change index performance, comes together with reduction of the degree of dispersion in the efficiency levels among the firms in the sector, as evaluated by the pure technical efficiency index evolution.

Table 13
Total factor productivity and its components
Manufacturing and assembly of automotive vehicles, trailers

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.170 | 0.905 | 0.979 | 1.196 | 1.059 |
| 1997-1998 | 1.074 | 0.922 | 1.014 | 1.059 | 0.991 |
| 1998-1999 | 0.774 | 1.141 | 0.890 | 0.870 | 0.884 |
| 1999-2000 | 0.293 | 3.500 | 0.709 | 0.414 | 1.027 |
| *Average* | *0.731* | *1.351* | *0.890* | *0.822* | *0.988* |

Table 13 above reports the statistics of "Manufacturing and assembly of automotive vehicles, trailers," which has an average TFP annual decrease of 1.2%. Figures indicate average positive annual change of 35.1% in the technical change index, in contrast with pure technical efficiency and scale change, which present average negative annual changes of 11% and 17.8%, respectively. Here we have, once more, a combination of an expansion of the production frontier with an increase in the degree of dispersion of the technical efficiency levels among firms.

Table 14
Total factor productivity and its components
Clothing and accessories

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.117 | 0.927 | 0.796 | 1.404 | 1.036 |
| 1997-1998 | 0.715 | 1.363 | 0.837 | 0.854 | 0.974 |
| 1998-1999 | 0.994 | 0.869 | 0.865 | 1.149 | 0.863 |
| 1999-2000 | 0.410 | 2.296 | 0.702 | 0.585 | 0.942 |
| *Average* | *0.755* | *1.260* | *0.797* | *0.947* | *0.952* |

The figures for "Clothing and accessories," shown in Table 14 above, indicate an average negative TFP change of 4.8%. The pure technical efficiency index average negative annual change of 20.3% ranks as the worst performance among all sectors whereas the technical change index positive annual change of 12.6% ranks as the second best. The only period in which the TFP index assumes a value greater than one, 1996-1997, records a strong positive performance of scale change. The familiar pattern of production frontier expansion and increasing pure technical efficiency dispersion recurs.

Table 15
Total factor productivity and its components
Nonmetallic metal ores

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.134 | 0.886 | 1.089 | 1.041 | 1.004 |
| 1997-1998 | 1.002 | 1.005 | 1.089 | 0.920 | 1.007 |
| 1998-1999 | 1.183 | 0.754 | 1.095 | 1.081 | 0.893 |
| 1999-2000 | 0.709 | 1.374 | 0.816 | 0.869 | 0.974 |
| *Average* | *0.988* | *0.980* | *1.014* | *0.974* | *0.968* |

The statistics for “Nonmetallic metal ores”, presented in Table 21 above, reports an average annual TFP of 3.2% in 1996-2000. This sector has the dubious distinction of presenting a contraction of the production frontier and an increase in the degree of dispersion of levels of technical efficiency among firms: the first one indicated by the technical change average negative annual rate of 2%, the second one pointed out by the (compounded) technical efficiency average negative annual rate of 1.2%.

Table 16
Total factor productivity and its components
Furniture and various industries

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 0.833 | 1.158 | 0.840 | 0.993 | 0.965 |
| 1997-1998 | 1.017 | 1.002 | 1.014 | 1.003 | 1.019 |
| 1998-1999 | 0.918 | 0.952 | 0.945 | 0.971 | 0.874 |
| 1999-2000 | 0.866 | 1.155 | 1.042 | 0.831 | 1.000 |
| *Average* | *0.906* | *1.063* | *0.957* | *0.947* | *0.963* |

Table 16 above presents the numbers of “Furniture and various industries.” The configuration is recognizable: an expansion of the production frontier, indicated by the technical change average positive annual rate of 6.3%, coupled with an increase in the degree of dispersion of levels of (compounded) technical efficiency, pointed out by the technical change average negative annual rate of 9.4%, yields an average negative annual TFP change of 3.7%.

Table 17
Total factor productivity and its components
Pulp, paper and paper products

| Sub-period | Technical Efficiency | Technical Change | Pure Technical Efficiency | Scale Change | Total Factor Productivity |
|---|---|---|---|---|---|
| 1996-1997 | 1.008 | 0.995 | 0.978 | 1.031 | 1.002 |
| 1997-1998 | 1.013 | 1.036 | 1.049 | 0.965 | 1.050 |
| 1998-1999 | 0.721 | 1.119 | 0.700 | 1.030 | 0.807 |
| 1999-2000 | 0.570 | 1.906 | 0.917 | 0.621 | 1.086 |
| *Average* | *0.805* | *1.218* | *0.901* | *0.893* | *0.980* |

The figures of "Pulp, paper and paper products", presented in Table 17, shown an average negative annual PTF rate of 2% in 1996-2000, with the recurrent pattern of an expansion of the production frontier at a positive average annual rate of 21.8% (technical change index) which is not enough to make up for the increase in the degree of dispersion of technical efficiency of 19.5% (technical efficiency index).

## 4. Conclusion

This paper estimates and decomposes the total factor productivity for 27 Brazilian industries during the period 1996-2000, 21 of those in the manufacturing division. The results show a negative annual average TFP growth for almost three quarters of the sectors analyzed. The poor performance affects both the mining and the manufacturing divisions: the manufacturing division records a TFP negative growth rate of 2.9%, not far from the 3.1% decline observed when both divisions are considered. Sectors recording an average annual TFP growth present a good performance in the scale efficiency index change in 57% of the cases. However, in the case of "Extraction of Mineral Coal," which presents a 10.8% TFP annual growth rate ranking as the highest one among all sectors analyzed, the technical efficiency index is the key factor behind the good outcome.

When we consider the periods 1996-1998 and 1998-2000, prior and posterior to the change in the exchange-rate regime from pegging the real to the dollar to let it float, the first period presents an average TFP growth rate of 2.9% whereas the second one shows a TFP average negative growth rate of 8.1%. Considering both the mining and the manufacturing divisions, technical change is the key component driving the TFP performance in 1996-1998; however, scale efficiency turns out to be more important to the manufacturing division. The period 1998-2000 shows a negative TFP growth rate of 8.1% for the whole industry and 9.6% for the manufacturing division. The worst performance is recorded in 1998-1999, which bears the weight of the exchange-rate regime in January. Whereas in 1996-1998 only 6 of the 27 sectors analyzed present average negative annual TFP growth rates -"Leather tanning, Manufacturing of Leather and Travel Products, and Footwear"; "Rubber and Plastic articles"; "Metal Products – except machines and equipment"; "Electronic Material and Communication Equipment"; "Furniture and Various Industries";

and “Recycling” - 25 of them do so in 1998-2000 – the two exceptions of average positive TFP growth rates being “Tobacco products” and “Wood products” in 1998-2000.

One interesting aspect of the numbers related to the 21 sectors reporting TFP positive growth rates in 1996-1998 is that 11 of them present a simultaneous average positive change in the technical change index and an average negative variation of the technical efficiency indicator. This suggests a possible avenue for public policy action: incentives for the dissemination of the best-practice production in order to reduce the degree of dispersion in the observed levels of firms’ technical efficiency.

## Appendix

*Table A*
*Averages results over 1996-2000 period*

| Sector | Technical Change | Pure Technical Efficiency | Scale Efficiency | Total Factor Productivity | Number of Firms |
|---|---|---|---|---|---|
| Extraction of mineral coal | 1.198 | 0.964 | 0.960 | 1.108 | 8 |
| Extraction of crude petroleum and related services | 0.991 | 0.986 | 1.017 | 0.993 | 6 |
| Mining of metal ores | 0.961 | 1.023 | 1.062 | 1.044 | 39 |
| Mining of nonmetallic minerals | 0.950 | 0.996 | 1.045 | 0.989 | 287 |
| Food products and beverages | 0.981 | 0.917 | 1.062 | 0.956 | 1812 |
| Tobacco products | 0.968 | 1.141 | 0.958 | 1.058 | 20 |
| Textile products | 0.913 | 0.996 | 1.042 | 0.947 | 647 |
| Clothing and accessories | 1.260 | 0.797 | 0.947 | 0.952 | 1040 |
| Leather tanning, manufacturing of leather and travel products, and footwear | 1.156 | 0.890 | 0.919 | 0.945 | 590 |
| Wood products | 1.163 | 0.979 | 0.888 | 1.011 | 626 |
| Pulp, paper and paper products | 1.218 | 0.901 | 0.893 | 0.980 | 415 |
| Editing, printing and reproduction of records | 0.875 | 1.045 | 1.004 | 0.919 | 486 |
| Coke, oil refining, preparation of nuclear fuel and alcohol | 1.164 | 1.032 | 0.803 | 0.964 | 143 |
| Chemical products | 0.791 | 1.024 | 1.188 | 0.963 | 823 |
| Rubber and Plastic articles | 0.985 | 0.970 | 1.000 | 0.955 | 926 |
| Non-metallic minerals | 0.980 | 1.014 | 0.974 | 0.968 | 1037 |
| Basic metallurgy | 0.998 | 0.996 | 1.023 | 1.018 | 310 |
| Metal products – except machines and equipment | 0.928 | 1.050 | 0.965 | 0.940 | 991 |
| Machines and equipment | 0.843 | 1.128 | 1.033 | 0.982 | 1013 |
| Office machines and computer equipment | 1.016 | 0.970 | 0.996 | 0.981 | 36 |
| Electrical machinery, apparatus and material | 0.951 | 0.901 | 1.192 | 1.022 | 359 |
| Electronic material and communication equipment | 0.892 | 1.003 | 1.072 | 0.959 | 132 |
| Medical and hospital instruments, precision instruments, etc | 0.937 | 1.022 | 1.045 | 1.000 | 166 |
| Manufacturing and assembly of automotive vehicles, trailers | 1.351 | 0.890 | 0.822 | 0.988 | 478 |
| Other transport equipment | 1.215 | 0.802 | 1.024 | 0.999 | 91 |
| Furniture and various industries | 1.063 | 0.957 | 0.947 | 0.963 | 932 |
| Recycling | 0.967 | 0.992 | 1.004 | 0.962 | 7 |
| *Average* | *1.026* | *0.977* | *0.996* | *0.984* | *497* |
| *Weighted Average** | *1.013* | *0.981* | *0.998* | *0.971* | *712* |

Source: IBGE (1996-2000)
The weights were defined as the sector's VAM participation on total VAM.

Table B
Sectors' Rank according to their total factor productivity

| Sector | 1996-2000 | | 1996-1998 | | 1998-2000 | |
|---|---|---|---|---|---|---|
| | TFP | Rank | TFP | Rank | TFP | Rank |
| Extraction of mineral coal | 1.108 | 1 | 1.265 | 1 | 0.971 | 7 |
| Tobacco products | 1.058 | 2 | 1.074 | 5 | 1.043 | 1 |
| Mining of metal ores | 1.044 | 3 | 1.120 | 2 | 0.973 | 5 |
| Electrical machinery, apparatus and material | 1.022 | 4 | 1.063 | 6 | 0.983 | 3 |
| Basic metallurgy | 1.018 | 5 | 1.058 | 7 | 0.980 | 4 |
| Wood products | 1.011 | 6 | 1.000 | 21 | 1.021 | 2 |
| Medical and hospital instruments, precision instruments, etc | 1.000 | 7 | 1.033 | 11 | 0.969 | 8 |
| Other transport equipment | 0.999 | 8 | 1.026 | 14 | 0.972 | 6 |
| Extraction of crude petroleum and related services | 0.993 | 9 | 1.104 | 3 | 0.893 | 23 |
| Mining of nonmetallic minerals | 0.989 | 10 | 1.076 | 4 | 0.910 | 18 |
| Manufacturing and assembly of automotive vehicles, trailers | 0.988 | 11 | 1.024 | 16 | 0.953 | 10 |
| Machines and equipment | 0.982 | 12 | 1.048 | 8 | 0.920 | 17 |
| Office machines and computer equipment | 0.981 | 13 | 1.041 | 9 | 0.925 | 16 |
| Pulp, paper and paper products | 0.980 | 14 | 1.026 | 15 | 0.936 | 11 |
| Non-metallic minerals | 0.968 | 15 | 1.005 | 18 | 0.933 | 14 |
| Coke, oil refining, preparation of nuclear fuel and alcohol | 0.964 | 16 | 1.031 | 12 | 0.901 | 20 |
| Chemical products | 0.963 | 17 | 1.039 | 10 | 0.892 | 24 |
| Furniture and various industries | 0.963 | 18 | 0.992 | 23 | 0.935 | 12 |
| Recycling | 0.962 | 19 | 0.971 | 27 | 0.954 | 9 |
| Electronic material and communication equipment | 0.959 | 20 | 0.985 | 25 | 0.935 | 13 |
| Food products and beverages | 0.956 | 21 | 1.029 | 13 | 0.887 | 26 |
| Rubber and Plastic articles | 0.955 | 22 | 0.983 | 26 | 0.927 | 15 |
| Clothing and accessories | 0.952 | 23 | 1.005 | 19 | 0.902 | 19 |
| Textile products | 0.947 | 24 | 1.010 | 17 | 0.888 | 25 |
| Leather tanning, manufacturing of leather and travel products, and footwear | 0.945 | 25 | 0.992 | 22 | 0.900 | 21 |
| Metal products – except machines and equipment | 0.940 | 26 | 0.990 | 24 | 0.894 | 22 |
| Editing, printing and reproduction of records | 0.919 | 27 | 1.003 | 20 | 0.842 | 27 |

Source: IBGE (1996-2000)

## References

Balk, B. (1998), Industrial Price, Quantity and Productivity Indexes. Boston: Kluwer Academic Publishers.

Caves, D. W. , Christensen, L. R., Diewert, W. E. (1982), "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity," *Econometrica* 50, 393-1414.

Färe, R. (1988), Fundamentals of Production Theory, Springer, Germany

Fare, R., Grosskopf, S., Norris, M and Zang, Z. (1994), Productivity growth, technical progress, and efficiency change in industrialized countries", *American Economic Review*, Vol. 84(1), pp.66-83.

Farell, M. J. (1957), "The Measurement of Production Eficiency," *Journal of Royal Statistical Society*, 120 (A), 253–281. Part 3.

Moorsteen, R.H. (1961). "On the Measuring Productive Potencial and Relative Efficiency". *Quarterly Journal of Economics* 75, 451-467.

Ray, S., Desli, E. (1997), "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Comment," *American Economic Review*, Vol. 87 (5) pp. 1033-39

Solow, R. (1957): "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics*, 39:312-320.

Young, A. (1995), "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics*, 110: 641-680.