# Nonparametric estimation of capacity utilization rates in Brazilian manufacturing sectors

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This paper uses the directional distance function and data envelopment analysis to estimate the capacity utilization rate in the manufacturing sectors in Brazil. The accounting and aggregate production information available from the Annual Industrial Survey constitutes the dataset of the work (PIA-IBGE). Capital stock estimates derived from expenses for investments and disaggregated depreciation rates are also calculated through the cost structure of companies. Results are evaluated considering the capacity utilization rate series as elaborated by the National Confederation of Industry (CNI).

Keywords. Capacity utilization, Directional distance function, Manufacturing industry.

JEL classification. D24, D92, E22, G31.

## 1. Introduction

Economists and policymakers have always given special attention to the industrial sector in terms of growth and development plans with medium and long-term perspectives. This happens due to the importance of the industrial sector in any country's economy of any. In Brazil, considering the development stage of its economy, industry is still the leading sector in terms of wealth generation, employment participation, labor income and tax revenue. Above all, industry is the main source of technological innovation in most countries.

Some basic statistics can help understand the relevance of the industrial sector in the Brazilian economy. In 2014, industrial GDP represented approximately 26% of the country's entire GDP according to the IBGE (Brazilian Institute of Geography and Statistics), which means that out of the total wealth generated in the country, about 1/4 was directly obtained through industrial activities. Naturally, we are not taking into account the indirect impact of industrial activities in upstream and downstream activities of each industrial segment. In general, regardless of the segment, the industrial sector has a large productive chain by nature, so its effects on income generation may be more significant than the direct effects.

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Also in 2014, industry was responsible for 24.3% of the stock allocation and formal employment in the Brazilian economy. On the other hand, in 2013, the industrial sector was responsible for 23% of the labor income in the country, as reported by the IBGE. This fact reveals that although the industrial sector (especially the manufacturing segment) is intensive in capital stock and therefore more sensitive to labor-saving technological innovation, its importance in the generation of formal employment and labor income is still large. Furthermore, considering the sector dynamics, the indirect effects multiply this importance.

Finally, it is interesting to introduce some statistics to clarify the importance of industry for tax collection technological innovation. With regards to tax collection nationwide, industrial activities were responsible for 21.5% of the ICMS (state value-added tax on goods and transportation and communication services) and 19% of IRPJ (corporate income tax) in 2014. In addition to that, industry was responsible for the entire revenue from IPI (tax on manufactured products), besides its participation in generating social contributions.[1]

Objective data on technological innovation is difficult to find, but it is possible to have an idea of the importance of industry in the innovation process by using the innovation expense as a reasonable proxy. According to PINTEC-IBGE data (Innovation Survey), in 2011, among the studied sectors (Extractive Industry, Manufacturing Industry, Electricity, Gas and Services), expenses for innovative activities in the Manufacturing Industry represented more than 77% of the total amount.

In general, the success or failure of a strategic plan at a macro or microeconomic level depends basically on two components: a solid cost-benefit analysis and information. Accurate information is a necessary condition for a competent cost-benefit analysis, so it is possible to say that the quantity and quality of information available for the preparation of a strategic plan is fundamental for its success.

Besides the unquestionable importance of understanding the industrial sector for economic planning purposes, it is necessary to highlight the relevance that industrial data has for the performance of diagnosis and prognosis of the country's economy. In the last 15 years, for example, there was strong growth in the number of academic works on the development and application of business cycle indicators. The use of leading, lagged and coincident indicators is standard practice in any study that seeks to understand and/or foresee the occurrence of an economic recession, as well as to assess its consequences. Whatever the method used to build such indicators, information on the industrial sector is widely used.

Among the information available on the industrial sector, the capacity utilization rate (CUR) is one of the most important economic activity indicators, as well as one of the most widely used worldwide. The reason for this is the conception of this indicator and the large amount of information that it is able to estimate it.

In principle, it is not necessary to have a deep understanding of the conceptual basis of the CUR to understand that such assessment relates what can be produced with

[1] Social contributions are (federal) taxes whose revenues are earmarked for specific purposes rather than going into the general fund.

what it is actually being produced. Although there is no consensus on the conceptual basis that defines CUR, it is well understood that the application of capacity utilization is related to fixities inherent to the technology used for the activity in question. The existence of such fixities is a phenomenon that only makes sense when the production of a firm or industry is restricted to a time horizon in which is not possible to change all inputs freely without incurring very high costs. Considering the usual terminology of production economic theory, they only make sense for short-run purposes.

In Brazil, the National Industrial Confederation (CNI) divulges monthly estimates of CUR based on direct research carried out among companies. However, as will be introduced later on, some studies suggest some unwanted characteristics that may be implicit in this method compared to others that rely on estimations through secondary data.

Considering this situation, the goal of this study is to introduce a CUR estimation method for 20 manufacturing sectors in Brazil between 1996 and 2012 based on statistics obtained from the Annual Industrial Survey (PIA-IBGE). The technology is modeled applying the concept of the directional distance function, originally introduced by Chambers et al. (1996), based on the benefit function proposed by Luenberger (1992) and on Shephard's distance function (Shephard, 1953). Subsequently, we apply data envelopment analysis (DEA) to estimate the industrial production frontier.[2] Once the frontier is estimated, it is possible to calculate the technical efficiency (TE) for each sector and period. Finally, TE estimates are used to calculate the CUR. As of this writing, we found no works applying the same technology in Brazil.

In Brazil there are no official statistics on capital stock in the industrial sub-sectors but there are data available on investments (capital expenditures) in the PIA-IBGE. Therefore, the perpetual inventory method (PIM) is used to estimate the capital stock. However, one difficulty when applying the PIM is the need to know the capital depreciation rate. In general, ad-hoc values varying between 7% and 10% are adopted without distinctions. Here we estimate the depreciation rate for each sector through data on expenses for depreciation that are also reported by the PIA-IBGE.

The following section introduces the main literature definitions and discussions on the capacity utilization and depreciation rate estimations, besides methodological aspects related to the CNI utilization capacity metric. In Section 3, we introduce the methods applied in this study for depreciation rate and CUR estimation purposes. Section 4 describes the applied database; Section 5 analyzes the main results, and Section 6 concludes.

## 2. Theoretical aspects

### 2.1 *Capacity Utilization Economics*

It is common for firms operate at a production level below what the existing inputs and equipment could produce. Since new investments require a certain period to mature

[2]The DEA model used to estimate the directional distance functions is often referred as the directional DEA. For a comprehensive introduction to DEA, please see Liu et al. (2013)

and increase production, companies seek to keep their capacity above the expected demand in order to react timely to positive shocks. Besides this, the nature of inputs, especially capital, due to their indivisibility, requires that companies to contract higher production potential than necessary, which also provokes higher revenues and greater negotiation power in the inputs market.

Psychological issues may also be important: a corporate manager may be more prone to expect future market expansion and for this reason he may wish to have excess capacity rather than a deficit. However, operating in a situation of excess capacity also implies financial costs for a company, such as the cost of maintaining equipment that is not operating and the depreciation to which it is subject. Therefore, a manager may opt for a moderate level of excess capacity.

Above all, in a near time horizon, capacity adjustment to the actual level of demand normally represents a high cost for the firm, or it can even be unfeasible due to legal or bureaucratic matters. Therefore, it is believed that fixed inputs are the main determinant for the existence of idle capacity, mainly in the industrial sector, as it is more intensive in the use of capital, which makes idle capacity a merely short-run phenomenon.

Corrado and Mattey (1997) define capacity utilization as the ratio between the current production level and the maximum sustainable output that can be obtained under normal production conditions considering the availability of production factors. Christiano (1981) defines it as the measurement of how the economy uses its available resources. Phillips (1963) describes the concern about measuring capacity utilization analogously to the efforts to obtain unemployment levels in the economy, both linked to the underuse of productive resources. As can be seen, the capacity utilization rate (CUR) has been widely discussed in literature as a way to measure idle levels of production factors, and the main motivation for its development is its relevance to calculation of economic price indexes.

It is well known that in situations in which the economy operates close to its capacity limit – keeping the level of added demand – the adjustment is made through the increase in prices, which provokes inflation until the investment can rebalance production capacity. Alves and da Silva Correa (2013) estimate the trajectory of a non-accelerating inflation rate of capacity utilization (NAICU) – in other words, the largest non-inflation generating CUR –, by obtaining the average value of 80.3% between 2001 and 2004 and 84% between 2011 and 2012. Admitting as a hiatus of installed capacity the difference between the observed CUR and the NAICU, the study concluded that the installed capacity hiatus is a relevant variable to explain the inflation of tradable goods, as the unemployment rate hiatus is significant for the inflation of non-tradable goods.

Some authors sustain that the relation between the CUR and inflation has weakened in the recent decades due to the rapid technological progress and the growth of international trade participation in national economies – see Corrado and Mattey (1997). The fact that this relation still remains as one of the most consistent in economics literature is reflected in subsequent economic conjuncture and monetary policy studies and prognoses that use capacity utilization data. Obviously, there are many other factors that determine inflation and monetary policies, such as demand variables.

There are authors who have adopted existing CUR series to obtain the portion of capital stock effectively used in the economy–production function inputs – generally taking the industrial CUR as an approximation to the capital utilization rate in the economy. da Silva Filho (2001) and Barroso and Others (2007) are examples of this approach.

However, there still is no clear consensus in the literature on the best way to measure CUR. Approaches include direct and surveys carried out among firms or the estimation of levels based on inputs, production and demand. Considering the first group, CUR statistics used in Brazil are tabulated by the National Confederation of Industries (CNI) and the Getulio Vargas Foundation (FGV) together with the industrial sector. In the international literature, a widely accepted reference is the research performed by the US Bureau of Census.

As for the second group, we are unaware of any data from studies seeking to empirically estimate the CUR for Brazil at this writing. For other countries, several different methods have been employed. As seen in the previous discussion, the most common way to define the capacity utilization rate (CUR) is through the ratio between a common production index $Y$ and a potential production index $Y^*$, in other words, $Y/Y^*$. This last aspect is where the Brazilian literature usually diverges, its being common to find two estimation lines: one from a strictly technological standpoint and the other under from the economic perspective.

From the technological point of view, Johansen (1968) defined the potential output as the maximum production that can be obtained for a certain period of time with the existing equipment, without restrictions on the use of variable inputs. This definition, which adopts the concept of a short-term production function, was later formalized by Färe (1984), who also introduced necessary and sufficient conditions for the existence of the potential production. Under this perspective, all useful information is synthesized in the production function. In this respect, the firm is the place where factors used to obtain the maximum output possible, observing the available technology and ignoring the economic environment aspects to which it is linked (Feijó, 2006, p. 617).

Afterwards, Fare et al. (1989) developed the first study that made Johansen's definition operational, introducing a CUR estimation method based on a linear programming model known as data envelopment analysis (DEA), where the production frontier is estimated in nonparametric fashion through observable production values and demand for inputs.

In the second CUR methodological estimation line, the potential output is calculated at a cost structure level for the firm, from a financial perspective. Considering that the total utilization of the physical capacity may not represent a marginal gain from the profit maximization point of view, the potential production is defined as the result of a rational corporate choice, which results in at least three definitions: the production level for which short and long-run average cost curves are tangent (Klein, 1960; Segerson and Squires, 1990); the output that minimizes the short-run average cost curve (Cassels, 1937; Hickman, 1964; Berndt and Morrison, 1981); and the one that considers the gap between the current output and the potential output (optimal short run) (Morrison, 1985a;b).

For Phillips (1963, p. 284), direct research has the advantage of extracting information from a "knowledgeable source". On the other hand, according to Christiano (1981, p. 166-176) there are difficulties in data interpretation, since it is not clear which potential output concept the corporate manager has in mind, since questionnaires do not always specify which one is to be adopted. For Christiano (1981), even if the potential output that meets the organization's "normal standards" is specified, it is still difficult to define it in terms of various product types.

Perry (1973, p. 710-718) analyzed the performance of four capacity assessments in American industry and obtained evidence that measurements based on direct research tend to result in a low cyclical bias. In other words, the CUR does not seem to increase (decrease) when the output grows (diminishes), unlike observations with other estimation methods. When responding surveys, "corporate people seem to 'find' capacity when the product grows and 'lose it' when it decreases."

Leeuw (1979) used U.S. Census Bureau data seeking to verify three possible reasons for the acyclic bias observed by Perry in direct research. The author concluded that the high occurrence of "non-variations" in the utilization rate may explain this behavior, as he noticed that units tend to repeat the last value registered a substantial number of times. Besides this, Leeuw (1979) considered the possibility of firms' using labor force as a CUR proxy, which would lead to bias considering the fluctuations in work productivity. Evidence suggests that this may also be an acyclic bias source.

Finally, Leeuw (1979) evaluated probable changes in normal condition hypotheses for company operations, more specifically, alterations in the amount of daily hours and weekly days in which a corporate manager bases the capacity notion related to high and low production phases. However, the evidence showed that this was not a significant factor.

As already stated, there are other reasons that can lead a firm to operate with idle capacity, besides the existence of fixed aspects. The technological approach, generally based on Johansen (1968), does not consider such research effects, although they are not different from values reported by direct research. This means that utilization levels originated from this kind of research tend to have lower levels compared to the technological approach. This topic is further studied by Christiano (1981, p. 173-174).

### 2.2 *CNI's measure of capacity utilization*

In Brazil, the National Industrial Confederation (CNI) performs a monthly estimation of installed capacity utilization in industrial sectors through a direct survey carried out among the companies.

In the sample design, 12 states participated, with industrial sectors that are together responsible for at least 70% of the industrial transformation value (ITV) or 50% of the employed population (EP) in the state industry, in a list that organizes industrial sectors from the most to the least representative ones. Once sectors for each state are defined, the number of units surveyed for a given state is set in such a way that participants have at least 60% of ITV and 40% of EP, with firms previously organized also from the most to the least relevant.

The companies are then asked to report their operational production capacity percentage used in normal operational conditions in the current month, applying the criterion of their choice. Percentages are added in two stages: in the first one, each industrial sector average is obtained for each state through the average utilization percentage reported by each local unit, considering the ratio between the number of hours worked in the company and the total of worked hours in all sector companies in the state.

In the second stage, the average percentage of each sector is obtained through the average state percentages, considering the number of employed persons;

$$TUCI_s^t = \sum_{e=1}^{n} TUCI_{s,e}^t W_{s,e},$$

where $TUCI_{s,e}^t$ is the utilization rate for activity sector $s$ in state $e$ for the reference month $t$; and $W_{s,e}$ is the weight of state $e$ in sector $s$, considering the participation of employed people in sector $s$, taking into account only the sample states.

### 2.3 *Capital depreciation*

For the estimation of the net stock through the perpetual inventory system, it is first necessary to establish the way in which capital depreciates through time. Fonseca and Mendes (2002) estimated Brazil's industrial capital depreciation rate using the value of immobilized assets from the 1975, 1980 and 1985 Industry Censuses as capital stock approximation together with the net investment flow through the polynomial-benchmark method, proposed by Nishimizu (1974). The results suggested an average depreciation rate of 13.21% for the 1975-1980 period and 15.27% for the 1980-1985 one.

In other studies, the depreciation rate is calculated by establishing hypotheses on the average life of different types of assets, together with a mortality function. In Brazil, Hofman (2000) adopted a lifetime of 50 years for residences, 40 for metallic structures and 15 for machinery and equipment, which are values similar to those adopted by the U.S. Bureau of Economic Analysis,[3] and linear depreciation rates. Morandi and Reis (2004) followed the same line, however allowing 20 years for machinery and equipment and geometric depreciation, as well as Marquetti (2009), who set 50 years for residential and non-residential structures and 14 years for machinery and equipment.

In this study, the capital stock depreciation rate is estimated based on a model in which the rate and the physical capital are determined simultaneously. The physical capital has a composition dynamics as proposed by the perpetual inventory system and the depreciation rate is defined as the average ratio of depreciation expenses with physical capital stock value.

[3] Ver Katz and Herman (1997).

## 3. Methodology

### 3.1 *Depreciation rate and capital stock*

This section introduces an industrial capital stock calculation method through the perpetual inventory system,[4] as well as the depreciation rate estimation method. Let $x_t$ be the depreciation expense of a given industrial sector during a period of time $t$ and let $K_t$ be the capital stock in $t$, The depreciation rate $\delta$ will be the solution to the equation:

$$x_t = \delta K_t \tag{1}$$

It is accepted that the capital stock in $t$ is the net capital stock from the previous period of time plus the investments made in the preceding period. Formally,

$$K_t = (1-\delta)K_{t-1} + I_{t-1}. \tag{2}$$

The capital stock $K_t$ may be expressed by the initial capital stock $K_0$, the investments made until the current date and the depreciation rate as:

$$K_t = (1-\delta)^t K_0 + \sum_{j=1}^{t} (1-\delta)^{j-1} I_{t-j}. \tag{3}$$

Assuming that investments grow at a technological progress rate $g$ and that the population growth is $n$, we have that the initial capital is related to the initial investment according to the following:[5]

$$K_0 = \frac{I_0}{g+n+ng+\delta}. \tag{4}$$

Where the technological growth rate $g$ is obtained from the hypothesis that output behaves as a deterministic rate of $Y_{t+1} = (1+g)Y_t$ and the initial investment is estimated using the average investment of the first five sample years,[6] which means that:

$$\frac{I_0}{L_1} = \frac{1}{5}\left(\frac{I_1}{L_1} + \frac{I_2}{(1+g)L_2} + \frac{I_3}{(1+g)^2 L_3} + \frac{I_4}{(1+g)^3 L_4} + \frac{I_5}{(1+g)^4 L_5}\right),$$

where $L_t$ is the active population in $t$.

Therefore, considering (4), the capital equation (3) is expressed by

$$K_t = \frac{(1-\delta)^t}{g+n+ng+\delta} I_0 + \sum_{j=1}^{t} (1-\delta)^{j-1} I_{t-j}. \tag{5}$$

In order to estimate the depreciation rate $\delta$, we apply (1) in (5) to obtain:

$$x_t = \frac{\delta(1-\delta)^t}{g+n+ng+\delta} I_0 + \sum_{j=1}^{t} \delta(1-\delta)^{j-1} I_{t-j}.$$

[4] Goldsmith (1951) was the first to use it, since when the method has been widely used for estimates of physical capital.

[5] The proof can be found in the appendix of Ferreira et al. (2010).

[6] Ferreira et al. (2010) and Bonzaninit et al. (2013) used that device as well.

Based on this, $\theta = n + g + ng$ permits proving that:

$$
\begin{aligned}
x_1 &= \left(\frac{1+\theta}{\theta+\tilde{\delta}_1}\right)\tilde{\delta}_1 I_0 \\
x_2 &= \left(\frac{1+\theta}{\theta+\tilde{\delta}_2}\right)(1-\tilde{\delta}_2)\tilde{\delta}_2 I_0 + \tilde{\delta}_2 I_1 \\
x_3 &= \left(\frac{1+\theta}{\theta+\tilde{\delta}_3}\right)(1-\tilde{\delta}_3)^2\tilde{\delta}_3 I_0 + (1-\tilde{\delta}_3)\tilde{\delta}_3 I_1 + \tilde{\delta}_3 I_2 \\
&\vdots \\
x_T &= \left(\frac{1+\theta}{\theta+\tilde{\delta}_T}\right)(1-\tilde{\delta}_T)^{T-1}\tilde{\delta}_T I_0 + (1-\tilde{\delta}_3)^{T-2}\tilde{\delta}_3 I_1 + \cdots + \tilde{\delta}_T I_{T-1}
\end{aligned}
$$

where $\tilde{\delta}_t$ is the solution to each corresponding equation above. Finally, we propose the following depreciation rate estimation:

$$\tilde{\delta} = \frac{1}{T}\sum_{t=1}^{T}\tilde{\delta}_t. \tag{6}$$

Consequently, the definitive equation for capital stock calculation for each industrial sector during a period of time $t$ is given by:

$$K_t = \frac{(1-\tilde{\delta})^t I_0}{g+n+ng+\tilde{\delta}} + \sum_{j=1}^{t}(1-\tilde{\delta})^{j-1} I_{t-j}. \tag{7}$$

### 3.2 *CUR based on the directional distance function*

This section introduces the way in which the CUR is estimated, applying the directional distance function concept created by Chambers et al. (1996) and generalized by Farrell (1957) and Shephard (1970). Let $x \in \mathbb{R}^m$ be the inputs vector and $y \in \mathbb{R}^n$ outputs vector. Then the technological set $T$ is given by:

$$T = \{(x,y) \mid x \text{ can produce } y\}. \tag{8}$$

By hypothesis, $T$ satisfies the following properties:

1. $T$ is convex;
2. $T$ is a closed set;
3. [Free Disposal of Inputs and Products] If $(x,y) \in T$, $\hat{x} \geq x$ and $\hat{y} \leq y$ then $(\hat{x},y) \in T$ and $(x,\hat{y}) \in T$.

We now consider $x_f$ as the fixed inputs sub-vector and $x_v$ the variable inputs sub-vector. Assuming the case of a single product ($n = 1$), the production frontier can then be defined as:

$$F(x_f,x_v) = \sup\{y \mid (x_f,x_v,y) \in T\}.$$

In this case, the CUR can be expressed by:

$$TUCI = \frac{F(x_f, x_v)}{\hat{F}(x_f)}, \tag{9}$$

where $\hat{F}(x_f) = \sup\{F(x) \mid x_v \geq 0 \text{ é livre}\}$, following Johansen (1968), is "the capacity utilization rate related to the maximum production level possible to be obtained based on the inputs quantity vector $(x_f, x_v)$, with the optimal production in a scenario in which it is possible to adjust the quantity of variable inputs $x_v$."

Following Shephard (1953), the distance function applied to the product is given by:

$$D_o(x_f, x_v, y) = \frac{y}{F(x_f, x_v)}.$$

In this case, the relation in (9) may be written as:

$$\frac{\hat{D}_o(x_f, y)}{D_o(x_f, x_v, y)}.$$

In a multi-product scenario, the distance function is defined as the maximum radial expansion possible of the product vector, which means that:

$$D_o(x, y) = \inf\{\theta \in \mathbb{R}_+^* \mid (x, y/\theta) \in T\}.$$

Another possible formulation is to adopt an additional linear expansion of $y$ in the direction of a vector $g_y$ of $D_o(x, y) = \sup\{\beta \mid (x, y + \beta g_y) \in T\}$ shape denominated directional distance. Therefore, the higher the value of $\beta^*$ that solves $D_o(x, y)$, the more evident the situation will be of productive inefficiency in which a firm is operating. Additionally, it is possible for inputs to be overused. For this reason, the directional distance function employed encloses a product expansion and an input retraction simultaneously. Consequently:

$$D_T(x, y; g_x, g_y) = \sup\{\beta \mid (x - \beta g_x, y + \beta g_y) \in T\}$$
$$\hat{D}_T(x_f, x_v, y; g_{x_f}, g_y) = \sup\{\beta \mid (x_f - \beta g_{x_f}, x_v, y + \beta g_y) \in T, x_v \geq 0\}.$$

Let $\beta^*$ be the optimal solution of $D_T(.)$ and $(x, y)$ be a feasible production plan, so the directional distance function projects $(x, y)$ at the point $(x - \beta^* g_x, y + \beta^* g_y)$ belonging to the frontier of set $T$, in the same direction of vector $(g_x, g_y)$.

Following Färe and Grosskopf (2000), it is possible to show that, based on the concepts introduced above, the CUR is given by the expression:[7]

$$TUCI_{DIR} = \frac{D_T(x, y; g_x, g_y) + 1}{\hat{D}_T(x_f, x_v, y; g_{x_f}, g_y) + 1}, \tag{10}$$

where the entered DIR is included, seeking to identify the estimation method.

[7] Notice that is possible to get the output distance function through specific values of $g_x$ and $g_{x_f}$ (by deleting both), so that definition generalizes the concept of Johansen for capacity.

Finally, $TUCI_{DIR}$ is estimated through the linear programming directional DEA, in which the technological set is given by:

$$T = \{(x,y) \in \mathbb{R}^n \times \mathbb{R}^m \mid \lambda X \leq x, \lambda Y \geq y, \lambda \geq 0,\ \lambda \in \mathbb{R}^k\},$$

where $X_{k\times n}$ is the inputs matrix and $Y_{k\times m}$ is the outputs matrix. The inverted inequalities satisfy restrictions to input minimization and output maximization purposes. The directional distance function can then be estimated by resolving the following linear programming problem:

$$\begin{aligned} D_T(x,y;g_x,g_y) \ = \ & \max_{\lambda,\beta} \ \beta \\ & s.t.: \ \lambda X \leq x - \beta g_x \\ & \lambda Y \geq y + \beta g_y \\ & \lambda \geq 0 \end{aligned}$$

with $\lambda \in \mathbb{R}^k$ and $\beta \in \mathbb{R}$. A frequently used simple option is to adopt $(g_x,g_y) = (x,y)$, so that the expansion direction of $y$ towards the technological efficiency frontier is the same as the original direction and the retraction direction of $x$ is the same as $-x$.

## 4. Database

Expenses and aggregate production statistics of 20 Brazilian processing industry sectors are used. We adopt the industrial transformation value (ITV)[8] as a product measurement standard. As inputs, we consider five variables:

1. Capital – estimated according to Section 3.1, based on expense statistics related to depreciation[9] and investment obtained through data available on purchases, improvements and fixed capital write-offs;
2. Labor – the addition of salaries, bonuses and other remuneration categories such as social costs (social security, private pensions and FGTS[10]) labor indemnities and benefits granted to employees;
3. Raw materials – the value of raw materials, additional inputs and other components, including gas and water purchased from other companies and used in the productive process;
4. Energy – amount spent on electricity considering it as a company production cost (includes fuel consumption used to operate machinery and heating costs in firms that have between 5 and 30 employees);

[8] This one is given by the difference between industrial GDP and operating costs.

[9] Expenses with depreciation of assets for operational or administrative use and amortization of tangible assets or pre-operating expenses and depletion of intangible assets – mineral and forest resources (in companies with a number of employees between 5 and 29 people, in addition to financial expenses, monetary variations and negative results of equity investments).

[10] FGTS is the "Guarantee Fund for Time of Service", a severance indemnity fund established by the Brazilian government into which employers must pay 8% of each worker's salary.

Table 1. Depreciation Rate for Manufacturing Industry in Brazil - 1996 to 2012.

| Sector | Value | Sector | Value |
|---|---|---|---|
| Wood | 0.223 | Transport Equipment | 0.134 |
| Motor Vehicles | 0.210 | Machinery and Equipment | 0.131 |
| Metallurgy | 0.168 | Electrical Equipment | 0.122 |
| Furniture and Others | 0.164 | Chemicals | 0.122 |
| Non-metallic Minerals | 0.158 | Food and Beverages | 0.108 |
| Textiles | 0.157 | Rubber and Plastic | 0.105 |
| Pulp and Paper | 0.155 | Metal Products | 0.102 |
| Oil Refining | 0.153 | Leather | 0.093 |
| Tobacco | 0.144 | Computer. Electronic and Optical Products | 0.088 |
| Wearing Apparel | 0.137 | Printing | 0.060 |

5. Maintenance – consumption of parts, accessories and small tools for the maintenance and repair of machinery and equipment.

Series are deflated by the Implicit Industrial GDP Deflator[11] and related to the number of employed staff.[12] They are also subject to Wilson's method (1993), which seeks to identify outliers in nonparametric efficiency frontier estimation problems. The results are significant for the existence of one upper outlier in the adopted sample: the oil sector, which will be considered in the results below.

## 5. Results

Unlike most papers in the literature, the depreciation rate method adopted in this study does not require any initial hypotheses on the useful life of assets or even on their mortality function. Rates are estimated yearly based on expenses observed, considering their average value in order to adjust them to the empirical evidence which demonstrates that the depreciation rate normally has low temporal volatility.

Seeking to minimize possible overestimations of data on depreciation expenses and considering circumstantial reductions in the payment of corporate income tax, we opted to perform an adjustment based on the observed variance. Therefore, equation 6 is now written as $\tilde{\delta}_s = \frac{1}{T}\sum_{t=1}^{T}\tilde{\delta}_{s,t} - \sigma_s$, where $\sigma_s$ is the standard deviation of depreciation rates for $s$. Table 1 reports the results obtained for each industrial sector.

It is important to highlight that for the most part, the depreciation literature approaches this issue within the context of capital stock for the entire economy. Since the industrial sector traditionally leads in technological innovation, it is expectable for the industry capital stock to be more intensive in machinery and equipment than other sectors, and therefore to present higher depreciation rates (according to evidence shown in the literature, as mentioned in Section 2.3, machinery and equipment depreciate faster).

[11] From the System of National Accounts (IBGE, 2000)
[12] PIA-IBGE.

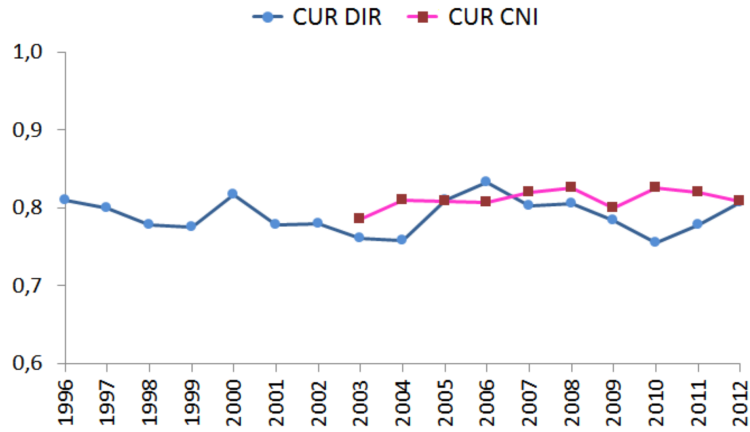



Figure 1. CUR of the Manufacturing Industry in Brazil - 1996 to 2012.

As for the CUR, the employed method estimates the utilization rate according to Johansen's definition in the context of technological production capacity, incorporating output- maximizing and input-minimizing technical efficiency. The results for the manufacturing industry are depicted in Figure 1 (CUR-DIR),[13] where we also introduce the capacity utilization series obtained from the CNI (hereafter denominated CUR-CNI).[14]

As mentioned before, measurements based on direct surveys have low cyclic amplitude with regards to other measurement means. This fact is also corroborated by the introduced assessments: the CUR-CNI indicator is significantly less susceptible to the variation of economic cycles than the CUR-DIR metric. The Figure 2 shows the density of probability functions of the two indicators and confirms that the CUR-DIR estimate has a more dispersed distribution and a slightly lower average than the CUR-CNI measurement.

In the sectoral analysis, CUR-DIR measurements have relevant variability and some sectors showed a much higher average utilization rate than others, such as clothing (95.7%), contrary to the printing sector (61.6%), which makes these sectors also representative of the existing gap with respect to the CUR-CNI, as a result of the low cyclic amplitude verified in this assessment.

With respect to standard deviation values for each sector, once again there is a prevalence of higher CUR-DIR dispersion in almost all sectors compared to the CUR-CNI dispersion. Therefore, in all aspects, CNI estimates proved to be more homogeneous and inertial.

Since the physical capital stock short-run inflexibility is normally accepted as one of the main reasons for the existence of idle capacity in industry, it is fundamental for capacity utilization assessment to be sensitive and negatively related to the capital volume employed in the production process. Firms with high capital dependence are more likely to operate with more slack productive capacity.

[13] The results in Figure 1 were obtained by taking the weighted mean across the sectors. The weight used was the participation of the workforce of a sector in the whole manufacturing industry.

[14] For CUR-CNI we used the mean of monthly statistics.

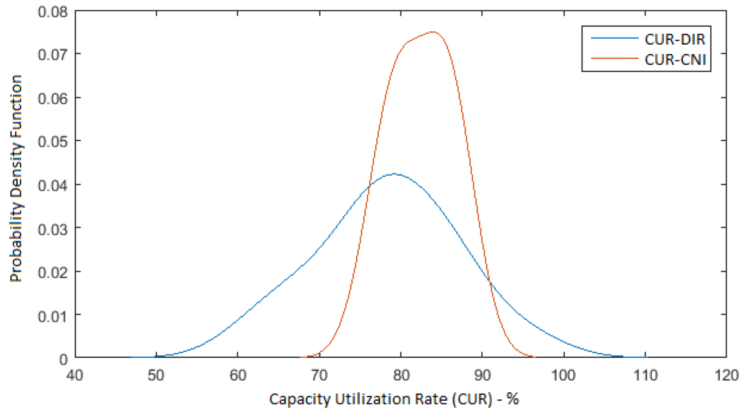



Figure 2. CUR - Empirical Probability Density.

Table 2. Descriptive Statistics for CUR-DIR and CUR-CNI - 2003 to 2012. ($\times 100$)

| Sector | CUR-DIR | | | | CUR-CNI | | | | Δ mean |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min | Max | Mean | SD | Min | Max | |
| Wearing Apparel | 95.7 | 7.5 | 80.7 | 100.0 | 81.5 | 1.1 | 79.7 | 83.0 | 14.2 |
| Electrical Equipment | 88.9 | 2.5 | 85.4 | 93.0 | 79.9 | 1.9 | 75.9 | 82.9 | 9.0 |
| Furniture and Others | 85.7 | 4.9 | 76.8 | 91.7 | 77.7 | 2.9 | 72.8 | 82.1 | 8.0 |
| Motor Vehicles | 86.9 | 3.6 | 81.6 | 91.8 | 86.0 | 2.2 | 83.0 | 89.2 | 0.8 |
| Chemical Products | 78.4 | 3.4 | 73.0 | 84.4 | 77.7 | 3.0 | 74.6 | 83.7 | 0.7 |
| Wood | 84.5 | 12.2 | 69.5 | 100.0 | 84.5 | 1.9 | 81.6 | 86.8 | 0.1 |
| Food and Beverages | 75.6 | 2.9 | 71.1 | 80.7 | 76.1 | 1.6 | 72.6 | 78.1 | −0.4 |
| Metal Products | 79.0 | 3.3 | 74.6 | 84.9 | 79.7 | 2.3 | 75.4 | 82.8 | −0.7 |
| Rubber and Plastic | 77.4 | 3.1 | 72.3 | 80.9 | 80.7 | 2.2 | 75.7 | 83.8 | −3.4 |
| Textiles | 80.5 | 2.8 | 75.3 | 85.8 | 84.5 | 1.3 | 82.0 | 86.4 | −4.1 |
| Transport Equipment | 83.4 | 4.6 | 76.3 | 88.5 | 88.3 | 2.4 | 84.1 | 90.9 | −4.8 |
| Leather | 79.7 | 4.0 | 72.5 | 85.6 | 86.0 | 2.2 | 82.4 | 89.4 | −6.3 |
| Non-metallic Minerals | 73.4 | 4.5 | 67.8 | 81.7 | 84.0 | 1.7 | 80.9 | 86.3 | −10.6 |
| Metallurgy | 75.6 | 3.8 | 68.8 | 81.7 | 86.6 | 5.1 | 73.5 | 91.4 | −11.0 |
| Machinery and Equipment | 67.2 | 2.4 | 63.2 | 70.7 | 80.3 | 2.0 | 76.6 | 83.1 | −13.0 |
| Pulp and Paper | 71.1 | 2.8 | 67.7 | 75.6 | 87.8 | 1.6 | 83.6 | 89.6 | −16.7 |
| Printing | 61.6 | 3.4 | 57.1 | 67.5 | 78.7 | 3.6 | 70.4 | 84.0 | −17.2 |
| Oil Refining | 65.6 | 7.2 | 56.8 | 75.2 | 85.0 | 2.9 | 80.3 | 90.6 | −19.5 |

Δ mean = difference of means.

In Figures 3 and 4, CUR estimates are introduced parallel to the respective capital mean participation in the output, from which a tendency line is drawn via an ordinary least square model. The results suggest a strong correlation of the CUR-DIR, with an $R^2$ of 65.7%, but a low correlation for the CUR-CNI, with only 1.1%. This fact illustrates what was initially observed in Figure 1: The CUR-CNI has low time variability when considering the aggregate amount for the processing industry and also when evaluating the sectoral rate, parallel to the capital participation in the production process.

In this last case, the printing industry, with capital participation of nearly 80.8%, has a CUR-CNI of 78.7%. The clothing industry, with a lower capital-product ratio, is lower

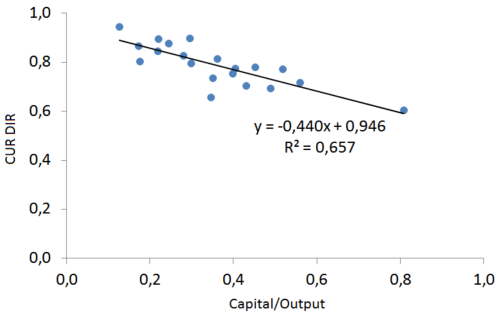



Figure 3. CUR-DIR and capital-output ratio.

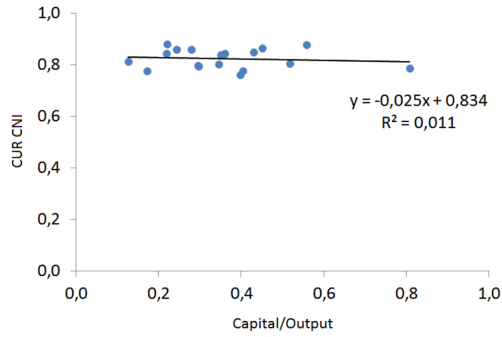



Figure 4. CUR-CNI and capital-output ratio.

(12.6%) and has a CUR-CNI of 81.5%. Far from being just an isolated case, sectors with the most diverse capital participations presented very similar CUR-CNI values, which seems to be in disagreement with capacity utilization literature.

## 6. Conclusion

This work uses data on production values and industry costs from the Annual Industrial Survey (PIA-IBGE) for Brazil and estimates the capital stock for the manufacturing sectors in order to obtain the capacity utilization rate through the nonparametric directional DEA method. Depreciation rate estimated for the industrial sectors show a possible overestimation bias. We also verified that values reported by the direct CUR-CNI survey have lower cyclic amplitude than the CUR-DIR assessment, as expected in the literature. We also found an inverse relation between estimated values and capital participation in the industrial sector output, with high significance. Therefore, the most capital-intensive sectors are most susceptible to low capacity utilization rates, which is in agreement with the theoretical effect of the existence of fixed capital in the CUR. This fact is even more prominent when compared to the CUR-CNI assessment, which presented an irrelevant correlation with regards to the capital/output ratio. Although CUR estimates require additional sensitivity and bias estimation analysis, these results reinforce the need for a more careful approach to the use of direct research as a capacity utilization estimation method and the importance of improving the accuracy of such estimations in Brazil.

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