THE DRIVERS OF DEINDUSTRIALIZATION IN BRAZIL (2000-2014): A DYNAMIC HIERARCHICAL-STRUCTURAL DECOMPOSITION ANALYSIS

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ABSTRACT

Abstract. The share of manufacturing in GVA in Brazil decreased during the period 2000-2014. The purpose of this work is to contribute to the dialogue around the drivers of such trend. In order to do so, input-output data were used to carry out a dynamic-hierarchical structural decomposition analysis (HSDA), which allows to directly decompose the variation of the manufacturing share into the effects of the variations of various possible drivers of deindustrialization: prices, domestic demand, technology, and foreign trade. As a result of the analysis, the following trends can be identified: a) most of the fall in the manufacturing share in GVA seems to be due to the effect of changes in prices and production techniques; b) the evolution of domestic demand contributes negatively, although not much, to the manufacturing share; c) foreign-trade related factors seems to contribute, in net terms, in a markedly positive way to the manufacturing share in GVA.

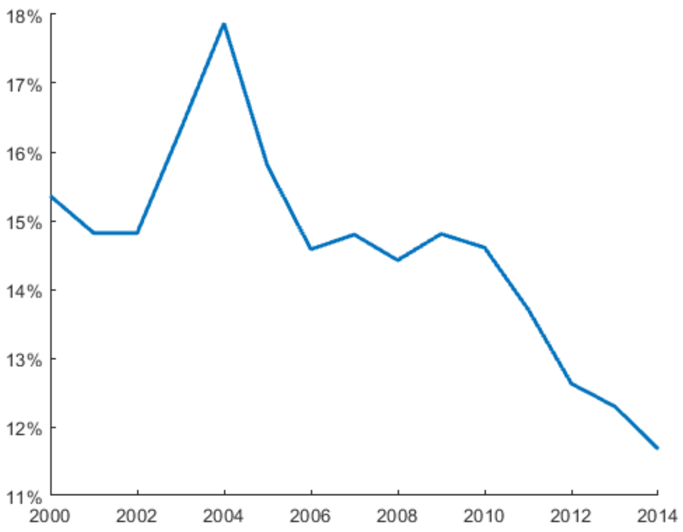
Keywords: Deindustrialization; Structural change; Input-output; HSDA.

Área 4: Microeconomia, economia industrial e estrutura produtiva

1. INTRODUCTION

As numerous studies have found, the share of manufacturing in total employment and gross value added (GVA) of the Brazilian economy has been declining since the beginning of the 21st century. According to data from the Release 2016 of World Input Output Database, as can be seen in Figure 1, the contribution of manufacturing to GVA in Brazilian economy fell from 15% to just over 10%, close to four percentage points.

Figure 1. Manufacturing share on gross value added (2000-2014).



According to scholars, this loss of manufacturing share could be explained basically through four trends: changes in relative prices, changes in composition of domestic demand, technological changes favorable to non-manufacturing products as intermediate inputs, and foreign-trade-related factors like changes in composition of exports or an increasing propensity to import manufactured products. The purpose of this work is to contribute to the dialogue around the greater or lesser relevance of these trends for the case of the Brazilian economy.

To achieve this purpose, input-output analysis was used to carry out a structural decomposition of the fall in the share of manufacturing in GVA in these trends identified by the literature; and it was do so using what is known as the dynamic "hierarchical-structural decomposition analysis" (HSDA). As applied to the present analysis, this method can be identified with the work of Koller and Stehrer (2009, 2010), representing the result of a set of contributions that trace through works by Liu *et al*. (1992), Rose and Casler (1996), and Dietzenbacher and Los (1998), among others, having reached its final form in Chen and Wu (2008).

In the present work, a dynamic HSDA method is applied to a first-order approximation to the so-called Leontief's ''open model'' in order to quantify the effect of a set of factors, considered approximately independent in the short-run, to the change in the share of manufacturing in GVA. In this way, the variation in the manufacturing share can be decomposed into the effects of the variation of eight factors: a vector of prices, a vector of taxes less subsidies per unit of product, a matrix of coefficients of total intermediate consumption at constant prices, a matrix of coefficients of imported intermediate consumption at constant prices, a vector of international transport margins per unit of product, a vector of coverage rates for final goods and services, a vector of domestic demand, and a vector of export demand. In order to be able to contribute to the debate on the drivers of deindustrialization of the Brazilian economy, the eight effects derived from the corresponding variations of the eight vectors and matrices considered were aggregated into four effects: a "price effect", a "domestic demand effect", a "technology effect", and a "foreign trade effect". These effects are completed with a residual factor that includes the effect of non-first-order terms, as well as the effect due to the change in the vector of taxes less subsidies per unit of product.

This analysis, though does not allow, strictly speaking, for contrasting any of the hypotheses formulated in the literature on the drivers of deindustrialization of the Brazilian economy, it does have the virtue of identifying certain trends. These trends are: a) most of the fall in the manufacturing share in GVA seems to be due to the effect of changes in prices and production techniques; b) the evolution of domestic demand contributes negatively, although not much, to the manufacturing share; c) foreign-trade related factors seems to contribute, in net terms, in a markedly positive way to the manufacturing share in GVA.

The structure of this paper is as follows. First (Section 2), the basic characteristics of the method used to estimate the data is exposed. Second (Section 3), the main results of the analysis are presented and discussed. Finally (Section 4), the most relevant conclusions are highlighted.

2. METHODOLOGY

The main objective of any decomposition analysis is to quantify which parts of the time variation of one variable can be attributed to the time variations of other variables, which are considered to be independent factors of the former. Thus, it is started from the expression of a variable z as a product of a set of n factors $x_1, x_2, \dots, x_n$:

$$z = x_1 x_2 \ \dots x_n$$

So that the time difference of the variable z between an initial time t_0 and a final time t_1 can be expressed as:

$$\Delta z = x_1(t_1)x_2(t_1)\ldots.x_n(t_1) - x_1(t_0)x_2(t_0)\ldots.x_n(t_0) \qquad (1)$$

And considering that each factor can vary while the remaining factors remain constant (*caeteris paribus*), the objective is to express the value of Δz as the sum of the respective effects of each determinant x_i:

$$\Delta z = Effect\,\Delta x_1 + Effect\,\Delta x_2 + \cdots + Effect\,\Delta x_n \qquad (2)$$

However, the way in which expression (2) can be derived from (1) is not unique, but consists of $n!$ different possibilities, all of them mathematically equally valid and exact. This is the so-called "non-uniqueness problem" (Dietzenbacher and Los, 1998). When faced with this problem, it is possible to adopt (in the manner of a pragmatic solution) the calculation of the arithmetic mean of the $n!$ possible solutions, which is itself an exact solution. However, this compromise solution presents at least two problems:

1. First, although all possible decompositions make mathematical sense, not all of them make theoretical sense. This is the so-called "relevance problem" (Chen and Wu, 2008; Kohler and Stehrer, 2009).

2. Secondly, if between the final instant t_1 and the initial instant t_0 there is a relatively long period of time, then the possible decompositions of (1) imply an assumed path for each independent variable that does not always correspond to the effective path, and this introduces a bias in the weighting of the different effects. This is the so-called "path problem" (Fernández-Vázquez *et al*., 2008).

To solve these two problems, different techniques have been developed that, in the end, have given rise to the method known as "dynamic hierarchical-structural decomposition" (Chen and Wu, 2008; De Boer, 2008; Koller and Stehrer, 2009, 2010). This method solves the indicated problems in two complementary ways:

1. To solve the "relevance problem", a method of decomposition is proposed whereby the total number of determinants is structured in such a way that they enter the total expression of z in a manner well defined by an assumed theoretical model. In this way, by introducing a hierarchy between the determinants, the consideration of theoretically insignificant decompositions is avoided, meanwhile reducing the number of calculations necessary.

2. To solve the "path problem", it is proposed that the expression (2) be obtained as if it were the result of integrating a differential:

$$\Delta z = \int_{t_0}^{t_1} \frac{dz}{dt}\,dt = \sum_{i=t_0+1}^{t_1} z(i) - z(i-1)$$
$$= \sum_{i=t_0+1}^{t_1} Effect\,[x_1(i) - x_1(i-1)\,] + \cdots + Effect\,[x_n(i) - x_n(i-1)]$$

In this way, taking into account the accumulated contribution of each effect, the weight of each of the effects on the total variation of z is determined by its actual path.[1]

This method can be applied to study the determinants of the variation in the share of manufacturing in GVA (or GDP at factor cost). So, if manufacturing GVA is denoted as y_{man} and total GVA as Y, then the share of manufacturing in GVA can be expressed as:

$$s = \frac{y_{man}}{Y}$$

[1] This solution to the "path problem" is possible only in the event that data is available for all of the time intervals that make up the period under study. Otherwise, econometric techniques must be used (Fernández Vázquez *et al*., 2008).

Taking this definition into account, and according to (1), the variation in manufacturing share can be expressed as:

$$\Delta s = \sum_{i=t_0+1}^{t_1} \left(\frac{y_{man}(i)}{Y(i)} - \frac{y_{man}(i-1)}{Y(i-1)} \right)$$

This expression, in turn, can be rewritten as:

$$\Delta s = \sum_{i=t_0+1}^{t_1} \left(\frac{\Delta y_{man}(i) - \Delta Y(i) \frac{y_{man}(i-1)}{Y(i-1)}}{Y(i)} \right) \qquad (3)$$

Where:

$$\Delta \mathrm{Y}\ (\mathrm{i}) = Y(i) - Y(i-1)$$
$$\Delta y_{man}(i) = y_{man}(i) - y_{man}(i-1)$$

Thus, according to (3), if it were possible to obtain, for each of the time intervals, Δy_{man} and ΔY as the sum of the effects of the variation of its components according to (2), then its accumulated contribution can be calculated as Δs. To this end, we arrive at the fundamental equation of the so-called Leontief's open model: :

$$\mathbf{x} = (\mathbf{I} - \mathbf{A} + \mathbf{N})^{-\mathbf{1}}(\mathbf{d} + \mathbf{e} - \mathbf{h}) \qquad (4)$$

Where **x** is the gross output vector, **A** is the matrix of coefficients of total intermediate consumption (also called matrix of ''technical coefficients''), **N** is the matrix of coefficients of imported intermediate consumption, **d** is the domestic final demand vector, **e** is the export demand vector, and **h** is the final import demand vector. From this identity, and given a vector of value added per unit of output **v**, total GVA or GDP at factor cost can be expressed as:

$$Y = \mathbf{v}^{\mathbf{T}}(\mathbf{I} - \mathbf{A} + \mathbf{N})^{-\mathbf{1}}(\mathbf{d} + \mathbf{e} - \mathbf{h}) \qquad (5)$$

In turn, the transposed vector $\mathbf{v}^{\mathbf{T}}$ can be expressed as the surplus of each sector's turnout over its operating costs (consisting of intermediate consumption, taxes less subsidies on products, etc.) per unit of output, so that:

$$\mathbf{v}^{\mathbf{T}} = \mathbf{i}^{\mathbf{T}}(\mathbf{I} - \mathbf{A} - \hat{\mathbf{t}} - \hat{\mathbf{m}})$$

Where **t** is a vector of taxes less subsidies on products per unit of output and **m** is a vector of international transport margins per unit of output. As usual, the "hat" symbol above the vectors denotes their expression as diagonal matrices. In turn, the relationship between domestic demand and imports can be expressed as:

$$\mathbf{d} - \mathbf{h} = \hat{\mathbf{n}}\mathbf{d}$$

Where **n** is a final demand coverage rate vector. Finally, given a vector of prices **p** and assuming that the price system is independent of the quantity system[2] and that some form of the purchasing power parity law

[2] This can only be the case if constant returns to scale prevail for all sectors and countries. Such assumption, despite being very restrictive, is typical of the so-called open Leontief system (Miller 2008, Ten Raa 2005).

applies[3], a matrix of coefficients of total intermediate consumption at constant prices $\tilde{\mathbf{A}}$ can be obtained, and a matrix of coefficients of imported intermediate consumption at constant prices $\tilde{\mathbf{N}}$, and, also, a vector of domestic and foreign demand at constant prices $\tilde{\mathbf{d}}$ and $\tilde{\mathbf{e}}$, according to the following expressions:

$$\tilde{\mathbf{A}} = \hat{\mathbf{p}}^{-1}\mathbf{A}\hat{\mathbf{p}} \rightarrow \mathbf{A} = \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1}$$
$$\tilde{\mathbf{N}} = \hat{\mathbf{p}}^{-1}\mathbf{N}\hat{\mathbf{p}} \rightarrow \mathbf{N} = \hat{\mathbf{p}}\tilde{\mathbf{N}}\hat{\mathbf{p}}^{-1}$$
$$\tilde{\mathbf{d}} = \mathbf{d}\hat{\mathbf{p}}^{-1} \rightarrow \mathbf{d} = \hat{\mathbf{p}}\tilde{\mathbf{d}}$$
$$\tilde{\mathbf{e}} = \mathbf{e}\hat{\mathbf{p}}^{-1} \rightarrow \mathbf{e} = \hat{\mathbf{e}}\tilde{\mathbf{d}}$$

So that (4) can be expressed as:

$$Y = \mathbf{i}^{\mathbf{T}}\left(\mathbf{I} - \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} - \hat{\mathbf{t}} - \hat{\mathbf{m}}\right)\left(\mathbf{I} - \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} + \hat{\mathbf{p}}\tilde{\mathbf{N}}\hat{\mathbf{p}}^{-1}\right)^{-1}\hat{\mathbf{p}}(\hat{\mathbf{n}}\tilde{\mathbf{d}} + \tilde{\mathbf{e}}) \tag{6}$$

Similarly, given another vector $\mathbf{v_{man}}$ whose elements are identical to $\mathbf{v}$ in those rows that represent manufacturing sectors and identical to zero in the remaining rows, then manufacturing GVA can also be expressed from (4) as:

$$y_{man} = \mathbf{v}_{\mathbf{man}}^{\mathbf{T}}(\mathbf{I} - \mathbf{A} + \mathbf{N})^{-1}(\mathbf{d} + \mathbf{e} - \mathbf{m}) \tag{7}$$

In turn, the transposed vector $\mathbf{v}_{\mathbf{man}}^{\mathbf{T}}$ can be expressed as:

$$\mathbf{v}_{\mathbf{man}}^{\mathbf{T}} = \mathbf{i}^{\mathbf{T}}(\mathbf{J} - \mathbf{AJ} - (\hat{\mathbf{t}} + \hat{\mathbf{m}})\mathbf{J})$$

Where $\mathbf{J}$ is a diagonal matrix whose elements are null for non-manufacturing sectors and equal to one for manufacturing sectors. Taking this equation into account, as well as the previous development that allowed the deduction of (6) from (5), then from (7) the following can be deduced:

$$y_{man} = \mathbf{i}^{\mathbf{T}}\left(\mathbf{J} - \hat{\mathbf{p}}\tilde{\mathbf{A}}\mathbf{J}\hat{\mathbf{p}}^{-1} - \hat{\mathbf{t}} - \hat{\mathbf{m}}\right)\left(\mathbf{I} - \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} + \widetilde{\hat{\mathbf{p}}\mathbf{N}}\hat{\mathbf{p}}^{-1}\right)^{-1}\hat{\mathbf{p}}(\hat{\mathbf{n}}\tilde{\mathbf{d}} + \tilde{\mathbf{e}}) \tag{8}$$

Expressions (6) and (8) already allow us to identify all the relevant elements for the structural decomposition analysis, in such a way that they seem valid expressions to obtain (3) as the result of the accumulated contribution of each effect. However, these expressions are highly non-linear, making it difficult to obtain an expression like (2) from which to calculate (3). To overcome this difficulty, it is possible to make a first-order approximation of both expressions. So, considering the definition of the Leontief inverse as:

$$\left(\mathbf{I} - \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} + \hat{\mathbf{p}}\tilde{\mathbf{N}}\hat{\mathbf{p}}^{-1}\right)^{-1} = \sum_{\mathbf{k}=\mathbf{0}}^{\infty}\left(\hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} - \hat{\mathbf{p}}\tilde{\mathbf{N}}\hat{\mathbf{p}}^{-1}\right)^{\mathbf{k}} \tag{9}$$

Then, if series (9) exists, its terms must tend toward the null matrix $\mathbf{0}$, and, accordingly, the terms of second order, third order, etc., must contribute less and less to the determination of Y and y_{man}. Also, since the matrices $\tilde{\mathbf{A}}$ and $\tilde{\mathbf{N}}$ are made up of elements significantly smaller than one, it is to be assumed that its convergence is quite fast, and that a first-order approximation to (6) and (8) can be a good approximation, so that:

$$Y \sim Y^{*} = \mathbf{i}^{\mathbf{T}}\left(\mathbf{I} - \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} - \hat{\mathbf{t}} - \hat{\mathbf{m}}\right)(\mathbf{I} + \hat{\mathbf{p}}\tilde{\mathbf{A}}\hat{\mathbf{p}}^{-1} - \hat{\mathbf{p}}\tilde{\mathbf{N}}\hat{\mathbf{p}}^{-1})\hat{\mathbf{p}}(\hat{\mathbf{n}}\tilde{\mathbf{d}} + \tilde{\mathbf{e}})$$

[3] Note that, since we are concerned with the evolution of the aggregates, in order for this approximation to be reasonable, it is sufficient that the weak version of the purchasing power parity hypothesis be fulfilled for tradable goods and services exclusively (*i.e.* those that are included in exports and imports of the countries).

$$y_{man} \sim y^*_{man} = \mathbf{i}^\mathbf{T}\left(\mathbf{J} - \widehat{\mathbf{p}}\widetilde{\mathbf{A}}\mathbf{J}\widehat{\mathbf{p}}^{-1} - (\hat{\mathbf{t}} + \widehat{\mathbf{m}})\mathbf{J}\right)(\mathbf{I} + \widehat{\mathbf{p}}\widetilde{\mathbf{A}}\widehat{\mathbf{p}}^{-1} - \widehat{\mathbf{p}}\widetilde{\mathbf{N}}\widehat{\mathbf{p}}^{-1})\widehat{\mathbf{p}}(\widehat{\mathbf{n}}\tilde{\mathbf{d}} + \tilde{\mathbf{e}})$$

For our sample, this first-order approximation represents no less than 78% of the actual value for all the aggregates and periods. Such first-order approximations have the virtue of being able to be manipulated until reaching an expression like (2) that can be calculated directly, without incurring in numerical approximations. In effect, developing both approximations and applying the commutative property in the multiplication of diagonal matrices, these approximations can be expressed as the row sum of the product of two matrices and a vector:

$$Y^* = \mathbf{i}^\mathbf{T}\widehat{\mathbf{p}}\widetilde{\mathbf{H}}\tilde{\mathbf{f}} \tag{10}$$

$$y^*_{man} = \mathbf{i}^\mathbf{T}\widehat{\mathbf{p}}\widetilde{\mathbf{H}}_{\boldsymbol{man}}\tilde{\mathbf{f}} \tag{11}$$

where:

$$\widetilde{\mathbf{H}} = \mathbf{I} - \widetilde{\mathbf{N}} - \widetilde{\mathbf{A}}\left(\widetilde{\mathbf{A}} - \widetilde{\mathbf{N}}\right) - (\hat{\mathbf{t}} + \widehat{\mathbf{m}})\left(\mathbf{I} + \widetilde{\mathbf{A}} - \widetilde{\mathbf{N}}\right)$$

$$\widetilde{\mathbf{H}}_{\mathbf{man}} = \mathbf{J} + \mathbf{J}\left(\widetilde{\mathbf{A}} - \widetilde{\mathbf{N}}\right) - \widetilde{\mathbf{A}}\mathbf{J}\left(\mathbf{I} + \widetilde{\mathbf{A}} - \widetilde{\mathbf{N}}\right) - (\hat{\mathbf{t}} + \widehat{\mathbf{m}})\mathbf{J}\left(\mathbf{I} + \widetilde{\mathbf{A}} - \widetilde{\mathbf{N}}\right)$$

$$\hat{\mathbf{f}} = \widehat{\mathbf{n}}\tilde{\mathbf{d}} + \tilde{\mathbf{e}}$$

In this way, expressions (10) and (11) represent a first-order approximation of the total GVA and the manufacturing GVA as the row sum of the product of a diagonalized vector of prices $\mathbf{p}$, a pair of input-output coefficient matrices at constant prices $\widetilde{\mathbf{H}}$ and $\widetilde{\mathbf{H}}_{\mathbf{man}}$, and a vector of final demand at constant prices $\mathbf{f}$. Thus, by means of a first-order approximation such as this, it is possible to clearly distinguish between real and nominal factors, explicitly considering in the analysis the role that prices may have played in the variation of manufacturing share. In fact, from such approximations, it is possible to obtain an expression analogous to (3) reflecting the variation in the share of the first-order components of manufacturing GVA in the first-order components of total GVA:

$$\Delta s^* = \sum_{i=t_0+1}^{t_1}\left(\frac{\Delta y^*_{man}(i) - \Delta Y^*(i)\dfrac{y^*_{man}(i-1)}{Y^*(i-1)}}{Y^*(i)}\right) \tag{12}$$

Considering that $y^*_{man}(i) = \beta(i)y_{man}(i)$ and $Y^*(t) = \alpha(i)Y(i)$, where α and β are parameters that represent the ratio of the first-order components to their actual value in each period i, previous expression can be rewritten as:

$$\Delta s^* = \sum_{i=t_0+1}^{t_1}\left(\frac{(\beta(i)y_{man}(i) - \beta(i-1)y_{man}(i-1)) - (\alpha(i)Y(i) - \alpha(i-1)Y(i-1))\dfrac{\beta(i-1)y_{man}(i-1)}{\alpha(i-1)Y(i-1)}}{\alpha(i)Y(i)}\right)$$

So, if $\alpha(i) \approx \alpha(i-1), \beta(i) \approx \beta(i-1)$, and $\frac{\beta(i)}{\alpha(i)} \approx 1$, then expression (12) would be a good approximation to (3). Fortunately, this is the case for our sample, being the variation between two contiguous periods of ratios $\alpha(i)$ and $\beta(i)$ less than 1% of their value for all the years of the sample, and being the ratio $\frac{\beta(i)}{\alpha(i)}$ greater than 0.92 for all the years of the sample.

The virtue of approximation (12) is that, from expressions (10) and (11), it is possible to apply the HSDA method in a relatively simple and direct way. Indeed, taking into account expressions (10) and (11), two decompositions can be obtained:

$$\begin{aligned}\Delta Y^*(i) = {} & Effect_Y\ \mathbf{\Delta p}(i) + Effect_Y\ \mathbf{\Delta\widetilde{A}}(i) + Effect_Y\ \mathbf{\Delta\widetilde{N}}(i) \\ & + Effect_Y\ \mathbf{\Delta t}(i) + Effect_Y\ \mathbf{\Delta m}(i) + Effect_Y\ \mathbf{\Delta n}(i) \\ & + Effect_Y\ \mathbf{\Delta\tilde{d}}(i) + Effect_Y\ \mathbf{\Delta\tilde{e}}\ (i)\end{aligned} \tag{13}$$

$$\begin{aligned}\Delta \mathrm{y}^*_{\mathrm{man}}(i) = {} & Effect_{y_{man}}\ \mathbf{\Delta p}(i) + Effect_{y_{man}}\ \mathbf{\Delta\widetilde{A}}(i) + Effect_{y_{man}}\ \mathbf{\Delta\widetilde{N}}(i) \\ & + Effect_{y_{man}}\ \mathbf{\Delta t}(i) + Effect_{y_{man}}\ \mathbf{\Delta m}(i) + Effect_{y_{man}}\ \mathbf{\Delta n}(i) \\ & + Effect_{y_{man}}\ \mathbf{\Delta\tilde{d}}(i) + Effect_{y_{man}}\ \mathbf{\Delta\tilde{e}}\ (i)\end{aligned} \tag{14}$$

Where, in order to avoid the so-called "relevance problem", each of the effects can be calculated according to the following hierarchical structure given by our own linear approach:

Diagram 1. Hierarchical decomposition

Value added at basic prices (total and manufacturing)

$$Y^* = \mathbf{i}^{\mathbf{T}}\mathbf{\widehat{p}\widetilde{H}\tilde{f}}$$

$$y^*_{man} = \mathbf{i}^{\mathbf{T}}\mathbf{\widehat{p}\widetilde{H}}_{\boldsymbol{man}}\mathbf{\tilde{f}}$$

Prices

$$\mathbf{\widehat{p}}$$

Input-Output coefficients at constant prices

$$\mathbf{\widetilde{H}} = \mathbf{I} - \mathbf{\widetilde{N}} - \mathbf{\widetilde{A}}\left(\mathbf{\widetilde{A}} - \mathbf{\widetilde{N}}\right) - (\mathbf{\hat{t}} + \mathbf{\widehat{m}})\left(\mathbf{I} + \mathbf{\widetilde{A}} - \mathbf{\widetilde{N}}\right)$$

$$\mathbf{\widetilde{H}_{man}} = \mathbf{J} + \mathbf{J}\left(\mathbf{\widetilde{A}} - \mathbf{\widetilde{N}}\right) - \mathbf{\widetilde{A}J}\left(\mathbf{I} + \mathbf{\widetilde{A}} - \mathbf{\widetilde{N}}\right) - (\mathbf{\hat{t}} + \mathbf{\widehat{m}})\mathbf{J}\left(\mathbf{I} + \mathbf{\widetilde{A}} - \mathbf{\widetilde{N}}\right)$$

Taxes less Subsidies on products $\mathbf{\hat{t}}$

International Transport Margins $\mathbf{\widehat{m}}$

Imported intermediate consumption $\mathbf{\widetilde{N}}$

Total intermediate consumption $\mathbf{\widetilde{A}}$

Final demand at constant prices

$$\mathbf{\hat{f}} = \mathbf{\hat{n}\tilde{d}} + \mathbf{\tilde{e}}$$

Coverage rates $\mathbf{\hat{n}}$

Domestic demand $\mathbf{\tilde{d}}$

Foreign demand $\mathbf{\tilde{e}}$

This hierarchical decomposition results from the first order approximations (10) and (11) and represents value added as a result of the interaction of three elements: final prices, inputs used and final demand. Thus, the composition of final demand at constant prices determines the real output of each sector, but value-added results from valuing this output at their actual prices after taking into account the inputs used and produced by each sector. Thus, this hierarchy reflects the intuition that value added is the surplus that each sector obtains over its turnout given a set of prices and given a production technology (in that case represented by the input-output coefficients). And, in this sense, it can better show the need to carry out a first-order approximation of the Leontief inverse matrix, since such approximation allows to easily introduce the role of prices in determining value added as a factor separate from the structure of inputs.

Taking this hierarchical structure into account, and in order to avoid the "problem of non-uniqueness", the average of all those exact decompositions that are compatible with such structure is calculated for each of the periods considered.[4] From here, the variation in the manufacturing share can be calculated as the accumulated contribution of the effects due to variation of each of the determinants plus a residual term,

[4] For details of the HSDA computation method, see Koller and Stehrer (2009).

resulting from the difference between the actual variation in each period and the variation of the first-order terms of the Leontief's ''open model'': :

$$\Delta s = \sum_{i=t_0+1}^{t_1} \Big(Effect\ \mathbf{\Delta p}\ (i) + Effect\ \mathbf{\Delta \widetilde{A}}(i) + Effect\ \mathbf{\Delta \widetilde{N}}(i) + Effect\ \mathbf{\Delta t}(i) + Effect\ \mathbf{\Delta m}(i) + Effect\ \mathbf{\Delta n}(i) + Effect\ \mathbf{\Delta \tilde{d}}(i) + Effect\ \mathbf{\Delta \tilde{e}}\ (i) + Res(i) \Big) \quad (15)$$

Where each of the effects is calculated from (3), so that, for example:

$$Effect\ \ \mathbf{\Delta p}(\mathrm{i}) = \frac{Effect_{y_{man}}\ \mathbf{\Delta p}(i) - Effect_{Y}\ \mathbf{\Delta p}(i) \frac{y_{man}(i-1)}{Y(i-1)}}{Y(i)}$$

And the remaining effects are computed in the same way. So, in order to summarize the information obtained through our decomposition analysis according to the topics mentioned in literature, effects into four categories were added:

- The "price effect", equal to the effect of the variation of the prices vector:
$$Price\ effect = Effect\ \mathbf{\Delta p}$$

- The "domestic demand effect", equal to the effect of the variation of the domestic demand at constant prices vector:
$$Domestic\ demand\ effect = Effect\ \mathbf{\Delta \tilde{d}}$$

- The "technology effect", equal to the effect of the variation of the matrix of coefficients of intermediate consumption at constant prices coefficient (or ''technical coefficients''):
$$Technology\ effect = Effect\ \mathbf{\Delta \widetilde{A}}$$

- The ''foreign trade effect'', equal to the effect of the variation of the coverage rates vector plus the effect of the matrix of coefficients of imported intermediate consumption at constant prices, plus the effect of the vector of international transport margins per unit of output, plus the effect of the export demand at constant prices vector:
$$Foreign\ trade\ effect = Effect\ \mathbf{\Delta n} + Effect\ \mathbf{\Delta \widetilde{N}} + Effect\ \mathbf{\Delta m} + Effect\ \mathbf{\Delta \tilde{e}}$$

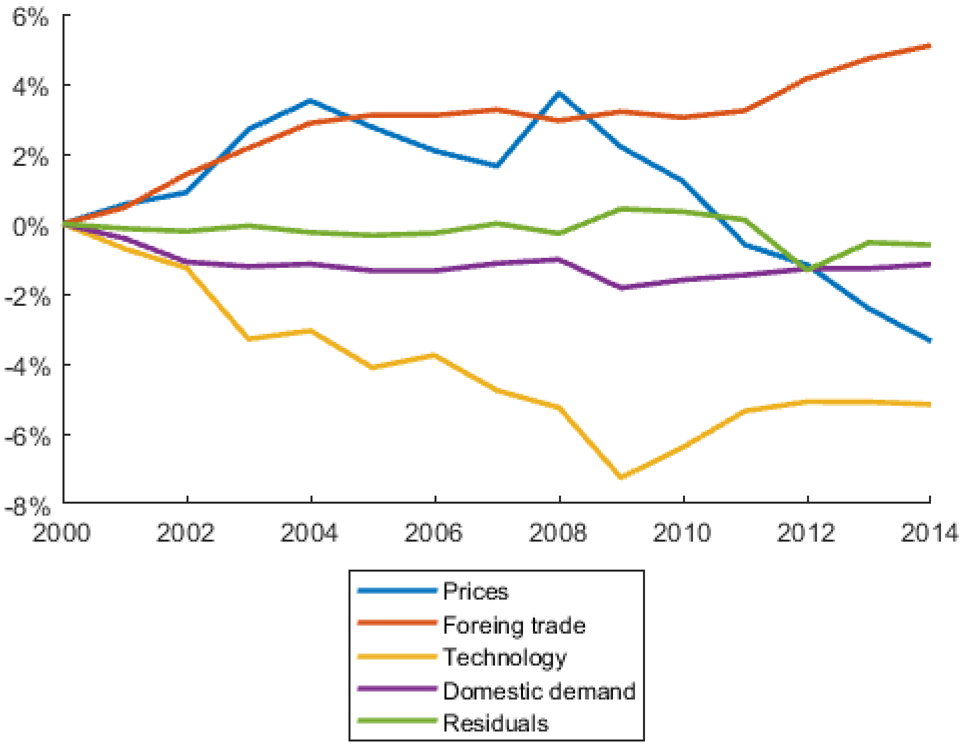
- The residual effects, equal to residuals itself, i.e., the difference between the actual variation and the variation due to the first-order terms of Leontief's model, plus the effect of the variation of the vector of taxes less subsidies on products per unit of output[5]:
$$Residual\ effects = Effect\ \boldsymbol{\Delta t} + Residuals$$

[5] The effect of taxes less subsidies, despite being an independent factor like the others, was included within the "residual effects" because it is so small that it is negligible.

3. RESULTS AND DISCUSSION

The method outlined in section 2 was applied to data available in the Release 2016 of the World Input Output Database corresponding to the Brazilian economy. Its main results can be shown in Figure 2, which shows the year-by-year contribution of each of the main effects to the manufacturing's share on GVA.

Figure 2. Contribution of main effects to manufacturing's share on GVA: (2000-2014).



In this way, based on the results of the analysis, as can be seen in Figure 1, it is possible to contribute some quantitative information to the discussion on deindustrialization in Brazil according to the topics mentioned.

Thus, in relation to the price effect, in Figure 1 it can be observed that the evolution of prices contributes positively to the share of manufacturing in GVA until 2004 and, from that year, with the exception of 2008, the evolution of prices contributes negatively to the manufacturing share. The total effect throughout the period considered implies a loss of more than three percentage points on GVA. In this way, it seems that, despite the conjuncture of the beginning of the century, there is a certain tendency for the evolution of prices to be such that it contributes negatively to the share of manufacturing in GVA. This result is consistent with the so-called "cost disease" (Baumol 1967, Nordhaus 2008) and has been widely identified as one of the determining factors of the loss of manufacturing share in GVA both in developed and less developed economies (Rowthorn & Wells 1987, Ngai & Pissarides 2007, Almon & Tang 2011, Herrendorf et al. 2015).

In relation to the foreign trade effect, in Figure 2 it can be observed that its contribution is positive for all the years analyzed, except for the period 2005-2011, so that its total contribution is positive. Thus, the net effect of foreign trade seems to have contributed an increase of five percentage points to the manufacturing share on GVA. These results are not fully consistent with the literature in this regard, because although it is true that there is a certain consensus among scholars about foreign trade as favoring industrialization of less developed countries (Krugman 1996), in the case of the Brazilian economy it was highlighted that foreign trade has induced a regressive specialization due to the boom in exports of raw materials and the appreciation of the Brazilian Real (Palma 2005, Bresser-Pereira 2010). According to the results of the present analysis, the negative effect of the appreciation of the Brazilian Real on manufacturing share seems to be observed, given that the period in which foreign trade does not contribute positively to the share is also the period in which the Brazilian Real were appreciated. However, it does not seem to be observed that the net effect of foreign trade as a whole, beyond short-term shocks such as those related to the exchange rate, is negative for the share of manufacturing, but rather, it seems that foreing-trade-related effects are positive.

Regarding the effect of technology, Figure 2 shows a clear tendency for changes in the type of inputs used to contribute to the deindustrialization of the Brazilian economy. Indeed, the total contribution of this effect over the period considered seems to imply a loss of manufacturing share of just over five percentage points. This effect, little observed in the literature, seems to have an important influence and could be due to factors such as outsourcing of services by manufacturing companies or the increasing use of business services as a result of the digitization of companies (Crozet & Milet 2017, Kelle 2013, Berlingeri & Marcolin 2018, Baldwin et al. 2015).

In relation to the effect of domestic demand, its total contribution seems slightly negative, so that it contributes with a loss of just over one percentage point to the share of manufacturing in GVA. This factor has been pointed out in the literature for the case of developed countries (Clark 1951, Gadrey 2003, Comín et al. 2017) and has been related to the different income elasticity of manufacturing with respect to non-manufacturing products. In the specific case of the Brazilian economy, it seems that some of this phenomenon is also occurring, although less markedly than in developed countries. Perhaps, the negative role that domestic demand has for participation in the case of Brazil may also have a certain relationship with inequality in income distribution, as main consumption may be due to a minority of the population that assimilates the consumption patterns of developed countries (Leite 2015, Cardoso 2021).

Finally, it is worth asking to what extent the results obtained through the present analysis are robust or depend on the approximations made or on defects in the data. Considering the behavior of the residues, a significant trend is not observed and, furthermore, its contribution to the variation in manufacturing share is barely half a percentage point. Thus, it seems that the approximation carried out does not imply the possibility of a significant bias in the analysis. Regarding the data used, the same conclusion cannot be made. Indeed, taking into account Figure 1, it is observed that the share of manufacturing in GVA as it appears in the database used shows a very irregular behavior, which must be due to defects in the elaboration of the database itself. This obviously affects the scope of the results obtained through this analysis and forces them to be considered provisional given the possibility that the data may be defective. In this sense, it is worth asking to what extent the results of the analysis that differ from the results of other scholars should be taken as proof against their hypotheses or as an indication of the defects of the database. Only further studies using other databases will be able to dispel this doubt.

6. CONCLUSIONS

Using a first-order approximation to the open Leontief model, it is possible to apply a dynamic hierarchical-structural decomposition analysis to estimate the determinants of the decline in manufacturing share in GVA for the case of the Brazilian economy. Thus, taking the data available in the 2016 Release of the World Input Output Database, it is possible to quantify the contribution of the main effects indicated in the literature to the case of the recent deindustrialization of Brazil. By performing this exercise, results are obtained, some of which are consistent with the literature, while others are not.

First, the results of the analysis carried out show that most of the fall in the manufacturing share in GVA seems to be due to the effect of changes in prices and production techniques. While the negative effect of prices on manufacturing share was pointed out repeatedly, the same is not the case with the negative effect of technology, which went unnoticed by many scholars.

Second, the results of the analysis also show that the evolution of domestic demand contributes negatively, although not much, to the manufacturing share. This is an aspect that was highlighted on several occasions by scholars regarding the case of developed countries. In the case of the Brazilian economy, this phenomenon seems to also occur, although it does not seem to be the main driver of the decline in manufacturing share.

Third, the results of the analysis show that foreign-trade related factors seems to contribute, in net terms, in a markedly positive way to the manufacturing share in GVA. This result is in open contradiction with many recent developments that linked the phenomenon of premature deindustrialization of Brazil with foreign trade. From the analysis carried out and for the period considered, it seems that there is not evidence enough to support this relationship, at least in a general way.

Finally, regarding the scope of the results, they should be considered with some skepticism since, although the approximation made seems relatively accurate, the data used could imply certain elaboration defects. Therefore, it is necessary to extend the analysis to other databases in order to check whether the results are robust or not.

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