Economic complexity and employment in Brazilian states

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Abstract

This paper has three objectives: (i) to identify promising sectors worth encouraging with a view to fostering the development of the Brazilian states; (ii) to evaluate the impact of economic complexity on the volume of employment; and (iii) to simulate how many new jobs would be created if each state were to become competitive in the activities considered promising for it. The results obtained vindicate the approach of the Economic Commission for Latin America and the Caribbean (ECLAC), which emphasizes the contribution of changes in the production structure to the development process, and reaffirm how important complexity is in improving the economic performance of countries or regions, whether this is measured by income or employment.

Keywords

Industrialization, industrial policy, production diversification, competitiveness, employment, economic development, regional development, regional economics, Brazil

JEL classification

O14, O25, O33

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I. Introduction

Changes in the production structure are an essential means of achieving higher levels of economic development (Lewis, 1954; Hirschman, 1961; Myrdal, 1960; Thirlwall, 2002). In particular, according to Furtado (1964), Prebisch (1950) and the other thinkers at the Economic Commission for Latin America and the Caribbean (ECLAC), underdevelopment is not a stage through which countries now at an advanced stage of development necessarily had to pass, but a historical process with particular characteristics.

The structuralist approach of ECLAC is based on the centre-periphery concept. As Rodríguez (2009) points out, there is an "original unequal development" in the world economy. The existence of developed economies creates a dynamic that tends to extend the development of those already developed (central) economies and to perpetuate the economic underdevelopment of developing (peripheral) economies. Thus, the fundamental characteristic of the centre-periphery approach is its focus on a particular systemic dynamic whereby inequality is inseparable from the performance of the system as a whole (Rodríguez, 2009, p. 84).

One effect of this division is slower average earnings growth in the periphery. Peripheral status tends to be continually reinforced and reproduced by its own dynamic and by interaction with the centre. While new production techniques have been introduced relatively quickly in the centre, the introduction of such techniques in the periphery is belated and slow. In peripheral countries, such know-how is disseminated only in sectors connected with export activity (Rodríguez, 2009, p. 81). This peculiarity of the periphery results in the predominance of "hybrid economies" where a capitalist core coexists peaceably with archaic production structures.

This process leads to symptomatic differences between the production structures of the centre and the periphery. The hybrid character of the peripheral economies creates two specificities: (i) production specialization (the commodity export sector is given priority in resource allocation); and (ii) structural heterogeneity, since sectors with high productivity and sectors with very low productivity coexist in the domestic economy. The countries of the centre, on the other hand, have just the opposite characteristics, possessing diversified and more homogeneous structures (Rodríguez, 2009). This difference in their production structures determines the process of economic development in the two groups.

The structuralist approach has returned to the forefront of the economic development debate in recent years as a result of the pioneering work of Hausmann, Hwang and Rodrik (2007) and Hidalgo and Hausmann (2009). These authors proposed a new methodology for calculating the sophistication of countries' products and production structures, based on the economic complexity approach. Using a modern method of analysing production structures that drew on disaggregated international trade data, they presented new evidence on the importance of structural change oriented towards more complex industrial sectors for the attainment of higher income and productivity growth.

More recent work has built on these studies to advance our understanding of the structural transformation process. However, it should be borne in mind that the way this process is coordinated differs by country. That is, less developed countries need a planned diversification strategy able to guide the production of more complex goods (Gala, Camargo and Freitas, 2017; Freire, 2017; Hartmann and others, 2020).

Considering this, some studies have used complexity indicators to design production diversification policies for developing countries (Hausmann and Chauvin, 2015; Hausmann, Santos and Obach, 2017; Romero and Freitas, 2018; Romero and Silveira, 2019). In the case of Brazil, the unwinding of the commodity boom highlighted the need for a redesigned production diversification strategy to increase the country's economic complexity and thereby boost its growth.

The objective of this study is to examine the obstacles associated with the structural differences between the Brazilian states (including the Federal District) and to propose a methodology for identifying promising sectors in order to promote the diversification of each state's production structure.[1] The complexity methodology was adapted for this purpose, with data on employment in economic activities being used instead of international trade data, a change that opened the way to new findings and yielded important empirical conclusions which served to quantify the concrete effects of increased economic complexity on the volume of employment. In addition, once the activities to be incentivized in each state had been identified, simulations were carried out to estimate the increase in employment in the event that the activities highlighted began to be carried out competitively.

The paper is divided into five sections, including this introduction. The second section presents the complexity methodology, which forms the methodological basis of the study. The third section analyses structural conditions in the states and presents the decision rule for selecting the activities that hold out the greatest potential for economic development in each. The fourth section details the estimates of the employment impact of complexity and the simulations of the employment impact in each state if the proposed diversification strategy is adopted. Lastly, the fifth section presents the final considerations of the paper.

II. Methodology

1. The economic complexity approach

The studies by Hausmann, Hwang and Rodrik (2007), Hidalgo and others (2007) and Hidalgo and Hausmann (2009), in particular, are milestones in the formulation of a new methodology for analysing the importance of structural change to development. These papers argue that the future performance of a country's economy will be substantially affected by which products it specializes in and produces competitively.

In their pioneering study, Hausmann, Hwang and Rodrik (2007) propose indicators that represent the first step in the formulation of the complexity methodology. They use the per capita incomes of countries that are competitive in the production of each product to infer their average productivity or sophistication. Thus, the sophistication index of product p is the weighted average of the per capita incomes of the countries that export it competitively:

$$PRODY_p = \sum_c \left[\frac{\left(X_{pc}/\sum_p X_{pc}\right)}{\sum_p \left(X_{pc}/\sum_p X_{pc}\right)} \right] Y_c \tag{1}$$

where X are exports of product p for country c, and Y is per capita income.

Similarly, Hausmann, Hwang and Rodrik (2007) define the sophistication index of country c as the weighted average of the sophistication of the products that the country exports:

$$EXPY_{ct} = \sum_p \left(\frac{X_{pct}}{\sum_p X_{pct}} \right) PRODY_p \tag{2}$$

As mentioned above, the products that countries specialize in predict future economic performance. $EXPY$ is thus the level of income or productivity of the basket of exported products. However, the index can sometimes be unreliable, as it is constructed with reference to countries' per capita income.

[1] As will be seen, this methodology is adapted from those proposed by Hausmann and Chauvin (2015), Hausmann, Santos and Obach (2017) and Romero and Freitas (2018).

This does not give due importance to each country's production structure, and the characteristics of each product are not measured as well as they might be, since it is enough for it to be exported by higher-income countries.

Hidalgo and Hausmann (2009) use the revealed comparative advantage (RCA) indicator proposed by Balassa (1965) to refine this methodological proposal. The index compares each product's share of the local market with the share of the same good in the world market. Once this is done, it is possible to infer how efficient each country is at producing a given product. Formally:

$$RCA_{pct} = \frac{X_{pct} / \sum_p X_{pct}}{\sum_p X_{pct} / \sum_c \sum_p X_{pct}} \quad (3)$$

The interpretation of the indicator is as follows: if the index value is over 1, the country is highly competitive in the production of the product analysed, while if it is under 1, the country is uncompetitive.

To develop the complexity measures, the authors measure country diversification and product sophistication. According to Hidalgo and Hausmann (2009), diversification refers to the amount of goods exported by the country with revealed comparative advantages, while the level of sophistication of a product is measured by its ubiquity, i.e., how many countries export the product concerned with revealed comparative advantages. Formally:

$$D_{ct} = \sum_p M_{pct} \quad (4)$$

$$U_{pt} = \sum_c M_{pct} \quad (5)$$

In this case, D stands for diversification and U for ubiquity. M represents a matrix in which a country takes the value 1 if it exports good p with revealed comparative advantages and 0 otherwise. The authors showed that complex countries tended to be highly diversified, while a complex product had a low degree of ubiquity. Moreover, diversification and ubiquity are negatively correlated measures, i.e., more diversified countries tend to produce goods with lower ubiquity.

However, although diversification and ubiquity are primary indicators of the complexity of each country and product, respectively, these measures are only initial approximations, and more refined measures of complexity can be obtained by combining the two (Hidalgo and Hausmann, 2011). According to Hausmann and others (2011), a poorly diversified country producing goods that are not very ubiquitous can be considered more complex than a poorly diversified country producing more ubiquitous goods. The same is true of ubiquity. A highly ubiquitous good produced by poorly diversified countries may be considered less complex than a highly ubiquitous good produced by highly diversified countries.[2]

In examining the relationships between diversification and ubiquity, Hausmann and others (2011) developed product and country complexity indices calculated by successive iterations between the indices. Analysing only the first iteration, in the case of the product complexity index (PCI), it is clear that the greater the diversification of the countries exporting a good and the lower its ubiquity, the more complex it is. In the case of the economic complexity index (ECI), the more diversified the economy and the less ubiquitous the goods produced and exported with revealed comparative advantages, the greater the complexity.

Another important contribution by Hidalgo and others (2007) concerns calculation of the proximity of products according to the probability of co-occurrence, as a way of capturing similarities in the

[2] This interaction between the diversification and ubiquity indicators has to be considered when looking at a case like diamonds, a good that has a low level of ubiquity but can be exported by undiversified countries. Hence the need to consider the two concepts in tandem. Without the interaction, to take a complementary example, undiversified countries producing goods with low levels of ubiquity may be mistaken for more complex ones.

capabilities required to produce goods.[3] In other words, the authors adopt the conditional probabilities of exporting with revealed comparative advantages to ascertain the proximity of two products in terms of the resources required to produce them. Thus, they calculate the probability of a good being exported, given that another good is already being exported. The authors define the level of proximity between two products (p and j) as:

$$\varphi_{p,j} = min\left\{P\left(RCA_j = 1 \mid RCA_p = 1\right), P\left(RCA_p = 1 \mid RCA_j = 1\right)\right\} \quad (6)$$

In this expression, for a country c:

$$RCA_{p,c} = \left\{1, if\ RCA_{p,c} \geq 1; 0, otherwise\right\} \quad (7)$$

The authors use proximity levels to form a network that connects the different products. In this network, called the product space, products that require similar capabilities tend to cluster together. In addition, the most complex products are located in the centre, while the least complex products are located in the outermost positions of the network (Hausmann and Klinger, 2006).[4]

To better examine the information implicit in the product space, Hausmann and others (2011) developed indicators to measure the ease with which competitiveness could be acquired in a given industry, considering the existing capabilities of the economy, and to indicate the new opportunities for development created by the acquisition of competitiveness in each industry.

Setting out from the assumption that products close to one another in the product space use similar production capabilities, Hausmann and others (2011) propose an index that measures how easy it is to produce a given good competitively with reference to the competitive production of nearby goods, which serves as a proxy for existing capabilities. This index, called the product density index (PDI), measures the proximity of a given product in relation to the country's current production structure (products with revealed comparative advantages), thus indicating how difficult it is for that country to achieve a comparative advantage in the product. This measure also reflects the amount of new production know-how that a region needs to acquire in order to manufacture and export a given product with comparative advantages. In other words, the lower the PDI, the more skills need to be acquired and the longer and more difficult or costly the process of acquiring revealed comparative advantages in that product will be. Thus, products which the country exports without revealed comparative advantages, but which have a high PDI, emerge as products with strong potential for competitiveness gains.

The PDI is calculated as the sum of the proximities (φ) of the products in which the country has revealed comparative advantages relative to product p, with the index being standardized by the sum of the proximities between all the products in the network relative to product p:

$$PDI_{pct} = \frac{\sum_p M_{ict} \varphi_{pi}}{\sum_p \varphi_{pi}} \quad (8)$$

Since more complex products generate higher income growth, it is important to analyse the gain generated by the acquisition of competitiveness in each product. Hausmann and others (2011) also formulate the complexity outlook gain index. From this, it is possible to measure the gain that a given

[3] The term "co-occurrence" can also be used to identify this relationship of proximity. In other words, the authors use the idea of proximity to calculate the likelihood of a good being produced, given that another specific good is already being produced.

[4] The configuration of the product space matches the centre-periphery definition advanced by ECLAC. The most complex products are in the centre and are therefore produced by central economies.

good brings by facilitating the production of more complex goods hitherto unproduced. A high value for this index means that the product is closer to other more complex products. Formally, the indicator is:

$$COGI_{pct} = \sum_p \frac{(1-M_{cit})\varphi_{pi} PCI_{it}}{\sum_p \varphi_{pi}} - (1-DI_{pct})PCI_{pt} \tag{9}$$

This methodology, shaped and systematized mainly by Hausmann and others (2011), is an essential part of the most modern approaches to economic complexity. The basic thesis centres on the perception that a country with a complex economy is one whose exports are dominated by non-ubiquitous and diversified products. From this, it is possible to understand the different levels of development characterizing each nation.

On the basis of the indicators described so far, it can be seen that the external market plays a key role in this methodology. However, the approach described here will not be based on export data, but on those for employment and economic activities. By contrast with the traditional interpretation, this adjustment allows consideration to be given to the domestic markets of the places concerned. Moreover, since the Brazilian economy is also largely centred on the domestic market, it can be better analysed by the interpretation using employment data.

This paper adapts the complexity approach to estimate the relationship between economic activities. According to Freitas (2019), the proximity between activities can be measured from the combination of occupations in the employment of different industries. In other words, just as it is possible to group products by the capabilities they require, it is also possible to aggregate industries by the occupations they make use of. This methodological process, known as "co-occupation", is also present in the work of Farjoun (1994) and is discussed in more detail in the next section.

2. Co-occupation and the measurement of indicators

According to Farjoun (1994), firms diversify through networks of industries that are interrelated in terms of the resources they need. The author thus considers it important to observe the similarities between resources (e.g., the human knowledge present in different occupations) in order to explain the diversification patterns of firms. On the basis of these groupings, which the author calls "resource-related industry groups", firms can share and transfer similar resources to benefit from and stimulate the diversification process (Farjoun, 1994, p. 188).

The ability to group firms by the resources they use can be interpreted similarly to the concept of co-occurrence of production capacities in nearby industries, as proposed by Hidalgo and others (2007).

The present research adapts proximity between products to find the proximity between industries with similar occupations. Freitas (2019) argues that the concept of co-occupation provides a basis for estimating the proximity of industries with similar employment profiles and using employment data to construct complexity indicators.

According to Freitas (2019), the first step is to define the effective occupations (EO) indicator, analogous to Balassa's (1965) index of revealed comparative advantage, as a basis for calculating the other complexity indicators from employment data. Applying the concept of co-occurrence, employment data will be used instead of export data as in equation (3). For this purpose, the index of revealed comparative advantage is calculated to capture effective occupations in each industry, as follows:

$$EO_{s,o} = \frac{emp_{s,o}/emp_s}{emp_o/emp} \tag{10}$$

where $emp_{s,o}$ is employment in occupation o in sector s and emp_s is total employment in sector s in the country. To supplement these, emp_o is total employment in occupation o in the country and emp is total employment in the country.

Thus, if the EO indicator is 1 or greater, the share of occupation o in sector s is greater than the share of that occupation o in the country as a whole, and so it is valid to say that the sector in question effectively provides employment for that occupation. Conversely, if the EO indicator is less than 1, the conclusion is that the sector does not effectively provide employment for that occupation in the location being analysed.

A second adapted indicator is the proximity indicator. This can be used to find the probability of an industry providing employment for a certain occupation given that another industry already does so. It is therefore a way of measuring the similarities between industries in terms of occupation. Thus, according to Freitas (2019), equation (4) can be adapted to ascertain the relationship between industries s and i as follows:

$$\theta_{s,i} = min\left\{P\left(EO_{io} = 1 \mid EO_{so} = 1\right), P\left(EO_{so} = 1 \mid EO_{io} = 1\right)\right\} \forall s \neq i \tag{11}$$

where for industry s:

$$EO_{s,o} = \left\{1, if \ EO_{s,o} \geq 1; 0, otherwise\right\} \tag{12}$$

Using these adaptations, it is possible to calculate the complexity indicators with the data on employment and economic activity. Lastly, in addition to the indices calculated, a general indicator encompassing all the others also needs to be constructed so that a production diversification strategy can be proposed, this being one of the objectives of the research.

III. Interpretation of the results

1. Analysis of production structures

Data from the 2010 annual social information report (RAIS) (Ministry of Economy, 2010) will be used to assess how complex activities are and which structures these activities are based on.[5] Compiled by the Ministry of Economy, RAIS is a database of employment data by economic activity. In this case, section C (manufacturing industry) and divisions 10 to 32 of version 2.0 of the two-digit National Classification of Economic Activities (CNAE 2.0) are considered. Thus, 23 activities will be analysed for the 27 units of the federation. Table 1 lists all activities considered in the research in order of complexity.

5 The year 2010 was chosen so that the results would not be biased by the current economic crisis and also so that the impact of the complexity indicators on the volume of employment in more recent years could be calculated afterwards.

Table 1
Brazil: economic activities in order of complexity

Code of the National Classification of Economic Activities, version 2.0 (CNAE 2.0)	Activities	Product complexity index	Classification
26	Electronic products	1.402	1
28	Machinery and equipment	1.378	2
27	Electrical products and materials	1.365	3
22	Rubber and plastic products	1.302	4
32	Miscellaneous products	1.302	5
29	Automotive vehicles	0.983	6
25	Metal products	0.973	7
18	Printing and reproduction of recordings	0.815	8
30	Other transport equipment	0.794	9
31	Furniture	0.647	10
21	Pharmochemicals and pharmaceuticals	0.495	11
20	Chemicals	0.432	12
12	Tobacco products	0.331	13
17	Paper and cellulose	0.179	14
24	Metallurgy	-0.332	15
23	Non-metallic mineral products	-0.445	16
14	Wearing apparel and garments	-0.468	17
10	Food products	-0.482	18
13	Textiles	-0.611	19
16	Wood products	-0.905	20
15	Leather and footwear	-1.154	21
11	Beverages	-1.427	22
19	Coke and oil derivatives	-1.428	23

Source: Prepared by the authors.

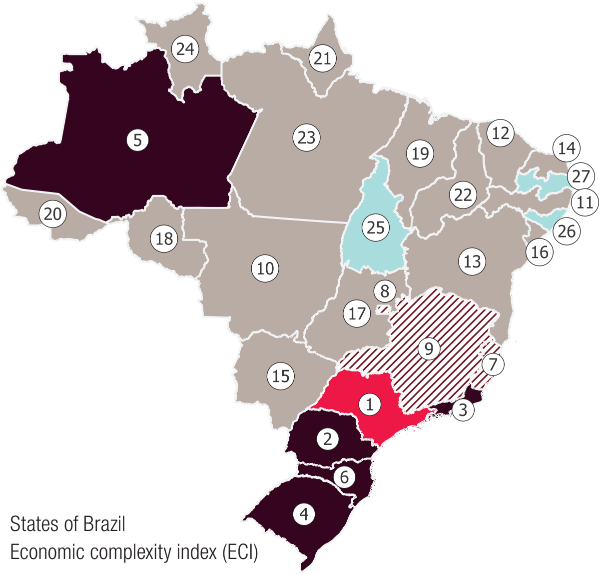
As can be seen in table 1, the most complex activities are those which apparently require the most production capabilities, while the least complex are more primary activities in which production does not require high levels of specification. The activity with the highest product complexity index value is electronic products, a less ubiquitous and more diversified sector. At the other extreme, the least complex activity is coke and oil derivatives.

Map 1 presents the levels of complexity of the Brazilian states, with the units of the federation ranked in descending order. The darker regions (red) represent higher standard deviations from the ECI and the lighter ones (light blue) lower standard deviations. The results show that states with lower levels of complexity predominate, as only the South and South-east regions, Amazonas and the Federal District have an ECI with a standard deviation greater than 0. In other words, all states that are not in this grouping have negative complexity indices.

Moreover, as can be seen, the South-east and South regions are exceptionally complex: São Paulo, Paraná and Rio de Janeiro are the states with the highest ECIs. At the other extreme, the North-east region is the least complex: Paraíba and Alagoas are the states with the lowest ECIs. A separate case, which does not follow the patterns of its region, is the state of Amazonas, which has the fifth-highest index because of production in the Manaus free trade zone. However, Amazonas' high ECI is not unexpected, as it is a maquila economy, like Mexico, whose ECI likewise overstates its real production capabilities.

Map 1

Brazil: economic complexity index (ECI) values of the units of the federation, 2010



Source: Prepared by the authors.
Note: The figures in brackets are the ECI values for each state.

2. Promising sectors for production diversification

As Hidalgo and Hausmann (2009) point out, increasing complexity has significant effects on the future economic performance of any country or region. Therefore, diversification proposals aimed at increasing complexity are essential to accelerate economic development.

With this in mind, Hausmann and Chauvin (2015) and Hausmann, Santos and Obach (2017) used complexity indicators to propose diversification strategies for Rwanda and Panama, respectively. As Hausmann, Santos and Obach (2017, p. 34) emphasize, this approach is very promising, as it is based on a methodology with a high degree of analytical rigour.

Setting out from these studies, an indicator was developed with the aim of classifying the three activities which have the greatest potential to increase each state's complexity depending on its particular production structure, and which should therefore be the focus of public development policies. Because this paper adopts a high level of aggregation, the option of identifying three activities opens up more opportunities for the states, since each category includes a great many subsectors that can be chosen. Moreover, picking out three options expands the amount of data that can be provided to policymakers. To this end, three dimensions are considered and will be given equal weight in the diversification rule: current capabilities, market opportunities and analysis of gain.

Table 2 shows how the indicator is constructed. Each of the three dimensions encompasses a number of indicators, all with the same weight. As finally formulated, the indicator represents the mean of the three dimensions. In listing the results, furthermore, it was necessary to remove activities in which each state already had revealed comparative advantages. Thus, for each state, all sectors whose index of revealed comparative advantages was higher than 1 were discarded. This process is necessary because the aim of the industrial policy approach to be pursued is to diversify the economy and not to specialize in sectors that are already competitive.

Table 2
Characterization of the product score index to produce a diversification proposal

Dimension	Weight	Indicator	Weight
Current capabilities	0.33	Number of jobs	0.25
		Value of revealed comparative advantage	0.25
		Sector density index	0.25
		Competitiveness opportunity (revealed comparative advantage greater than 0.5)	0.25
Market opportunities	0.33	Value imported in Brazil	0.50
		Value imported in the world	0.50
Analysis of gain	0.33	Sector complexity index	0.50
		Complexity outlook gain index	0.50

Source: Prepared by the authors.
Note: Within the dimensions, the indicators were standardized (from 0 to 1) to estimate the scores. The weights assigned to each indicator are also instruments of analysis that depend on the purpose they are intended for. The decision in this case was to use equal weights.

Four indicators are used to characterize existing capabilities in each unit of the federation: (i) the number of jobs per activity; (ii) revealed comparative advantage; (iii) the sector density index (to measure the gap between the existing production structure and the one required by the sector analysed); and (iv) the competitiveness opportunity (an extra weight is assigned to products with a revealed comparative advantage score above 0.5 in order to highlight the easiest opportunities for competitiveness gains).

To measure the market opportunities of each sector, two indicators are considered: (i) the value imported in Brazil; and (ii) the value imported in the world. In contrast to the other indices, the data for this second dimension are not employment data but trade data and therefore have a different classification. To reconcile these data with the employment classification, import data classified in the two-digit Harmonized Commodity Description and Coding System (HS 2007) were matched with those in CNAE 2.0 (see table A1.1 in annex A1). Brazil's import data were obtained from the COMEX STAT platform of the Ministry of Development, Industry and Trade, while world import data were taken from the United Nations Comtrade database.

The last dimension considers the possibility of gains from the acquisition of revealed comparative advantages in the sectors analysed. Two indicators are used for this: (i) the sector complexity index (determined by the product complexity index of the activity); and (ii) the complexity outlook gain index, which measures the opportunities created by the competitive production of the new product for the subsequent production of more complex products.

Following this rule, the sectors were ranked by score and the three with the highest values for each unit of the federation were selected, with the proviso that each activity could be repeated six times at most. As there were only 23 activities for 27 states, the probability of repetition was high. The maximum number of repetitions, six, was chosen in view of the scope this still left within each section of CNAE 2.0. In other words, this limitation notwithstanding, there are many activities within each section (an average of 4.5), allowing states to specialize simultaneously in the same one. On the basis of this decision rule and the production structure as of 2010, the sectors holding out the most promise for the development of the states are as presented in table 3.

Table 3
Brazil: promising economic activities in each unit of the federation

Unit of the federation	National Classification of Economic Activities, version 2.0 (CNAE 2.0)	Activity	Revealed comparative advantages	Complexity outlook gain index	Product density index	Score
AC	27	Electrical products and materials	0.031	0.177	0.100	0.961
AC	29	Automotive vehicles	0.008	0.187	0.103	0.196
AC	26	Electronic products	0.001	0.206	0.103	0.077
AL	27	Electrical products and materials	0.012	0.165	0.112	0.987
AL	20	Chemicals	0.800	0.192	0.138	0.347
AL	28	Machinery and equipment	0.098	0.139	0.116	0.294
AP	11	Beverages	0.891	0.292	0.093	0.583
AP	29	Automotive vehicles	0.006	0.173	0.098	0.333
AP	28	Machinery and equipment	0.004	0.140	0.091	0.306
AM	28	Machinery and equipment	0.512	-0.340	0.275	0.309
AM	24	Metallurgy	0.453	0.055	0.287	0.101
AM	21	Pharmochemicals and pharmaceuticals	0.032	-0.022	0.250	-0.113
BA	10	Food products	0.428	0.467	0.397	0.210
BA	29	Automotive vehicles	0.416	0.059	0.340	0.203
BA	23	Non-metallic mineral products	0.714	0.471	0.377	0.035
CE	26	Electronic products	0.179	0.107	0.161	-0.031
CE	30	Other transport equipment	0.157	0.119	0.157	-0.097
CE	21	Pharmochemicals and pharmaceuticals	0.372	0.189	0.177	-0.098
ES	19	Coke and oil derivatives	0.428	0.624	0.394	0.426
ES	28	Machinery and equipment	0.257	-0.180	0.359	0.284
ES	10	Food products	0.649	0.281	0.368	0.142
FD	27	Electrical products and materials	0.029	0.128	0.056	1.273
FD	28	Machinery and equipment	0.034	0.103	0.055	0.515
FD	18	Printing and reproduction of recordings	0.304	0.149	0.075	0.513
GO	20	Chemicals	0.741	0.193	0.211	0.310
GO	23	Non-metallic mineral products	0.924	0.336	0.220	-0.006
GO	24	Metallurgy	0.211	0.344	0.208	-0.037
MA	27	Electrical products and materials	0.005	0.143	0.129	0.969
MA	23	Non-metallic mineral products	0.927	0.245	0.153	0.506
MA	19	Coke and oil derivatives	0.476	0.277	0.164	0.467
MT	23	Non-metallic mineral products	0.914	0.254	0.199	-0.052
MT	24	Metallurgy	0.133	0.254	0.169	-0.060
MT	30	Other transport equipment	0.045	0.114	0.149	-0.131
MS	14	Wearing apparel and garments	0.653	0.259	0.153	0.054
MS	11	Beverages	0.703	0.360	0.136	-0.015
MS	26	Electronic products	0.010	0.159	0.115	-0.015
MG	30	Other transport equipment	0.236	-0.037	0.399	-0.067
MG	13	Textiles	0.927	0.421	0.367	-0.112
MG	16	Wood products	0.551	0.506	0.422	-0.152
PA	19	Coke and oil derivatives	0.175	0.493	0.250	0.453
PA	10	Food products	0.756	0.341	0.240	0.335
PA	23	Non-metallic mineral products	0.843	0.367	0.228	0.100
PB	26	Electronic products	0.130	0.202	0.119	-0.017
PB	21	Pharmochemicals and pharmaceuticals	0.016	0.245	0.144	-0.044
PB	14	Wearing apparel and garments	0.474	0.291	0.148	-0.069
PR	13	Textiles	0.730	0.188	0.467	-0.183
PR	15	Leather and footwear	0.380	0.385	0.477	-0.190
PR	30	Other transport equipment	0.069	-0.426	0.440	-0.198

Unit of the federation	National Classification of Economic Activities, version 2.0 (CNAE 2.0)	Activity	Revealed comparative advantages	Complexity outlook gain index	Product density index	Score
PE	19	Coke and oil derivatives	0.625	0.497	0.292	0.480
PE	20	Chemicals	0.641	0.151	0.252	0.300
PE	24	Metallurgy	0.385	0.321	0.259	0.035
PI	19	Coke and oil derivatives	0.306	0.316	0.174	0.520
PI	20	Chemicals	0.090	0.187	0.144	0.270
PI	10	Food products	0.359	0.217	0.160	0.227
RJ	20	Chemicals	0.629	-0.181	0.515	0.357
RJ	28	Machinery and equipment	0.469	-0.580	0.509	0.332
RJ	29	Automotive vehicles	0.227	-0.367	0.502	0.231
RN	11	Beverages	1.000	0.618	0.248	0.056
RN	23	Non-metallic mineral products	0.953	0.326	0.236	-0.004
RN	15	Leather and footwear	0.218	0.514	0.271	-0.029
RS	24	Metallurgy	0.770	0.094	0.389	-0.077
RS	30	Other transport equipment	0.256	-0.302	0.389	-0.111
RS	14	Wearing apparel and garments	0.613	0.181	0.404	-0.191
RO	27	Electrical products and materials	0.006	0.158	0.105	0.986
RO	29	Automotive vehicles	0.033	0.174	0.104	0.220
RO	26	Electronic products	0.013	0.192	0.104	0.089
RR	29	Automotive vehicles	0.003	0.178	0.065	0.396
RR	26	Electronic products	0.010	0.216	0.064	0.386
RR	18	Printing and reproduction of recordings	0.050	0.209	0.068	0.140
SP	14	Wearing apparel and garments	0.904	0.036	0.623	-0.228
SP	11	Beverages	0.974	0.610	0.635	-0.314
SP	31	Furniture	0.859	-0.640	0.626	-0.345
SC	15	Leather and footwear	0.732	0.473	0.467	-0.157
SC	30	Other transport equipment	0.697	-0.295	0.406	-0.187
SC	21	Pharmochemicals and pharmaceuticals	0.107	-0.096	0.372	-0.303
SE	20	Chemicals	0.900	0.199	0.229	0.394
SE	10	Food products	0.506	0.319	0.251	0.196
SE	24	Metallurgy	0.030	0.349	0.224	-0.058
TO	27	Electrical products and materials	0.018	0.175	0.090	0.966
TO	19	Coke and oil derivatives	0.941	0.255	0.145	0.938
TO	10	Food products	0.696	0.204	0.143	0.680

Source: Prepared by the authors.

Note: The values presented in the table are unstandardized. Although all the indices employed were standardized to produce the score indicator, the original values before standardization were used to better identify the characteristics of each sector in the states.

The states are Acre (AC), Alagoas (AL), Amapá (AP), Amazonas (AM), Bahia (BA), Ceará (CE), Espírito Santo (ES), Federal District (FD), Goiás (GO), Maranhão (MA), Mato Grosso (MT), Mato Grosso do Sul (MS), Minas Gerais (MG), Pará (PA), Paraíba (PB), Paraná (PR), Pernambuco (PE), Piauí (PI), Rio de Janeiro (RJ), Rio Grande do Norte (RN), Rio Grande do Sul (RS), Rondônia (RO), Roraima (RR), São Paulo (SP), Santa Catarina (SC), Sergipe (SE) and Tocantins (TO).

From the results presented in table 3, it can be seen that the diversification options were fewer in the more complex states, where there are a great many sectors with comparative advantages. In other words, since a high level of aggregation was applied to activities, the more complex states were left with lower-scoring, uncomplex ones because, as mentioned above, there was already a substantial number of complex activities with revealed comparative advantages.

Consequently, some states need differentiated public policies. São Paulo, for example, is the state with the highest complexity, and the diversification proposal based on the indicator calculated consists of three sectors that may have the effect of reducing its complexity, because although specialization in these activities would increase diversification, the average ubiquity of the state could also rise, which is a negative. Even so, the proposal for São Paulo was kept for information purposes and also so that this problem could be examined. In view of this limitation, it is important to use more disaggregated classifications of the CNAE 2.0 in similar studies in the future.

There are two other important points to note. The situation in the Federal District and Tocantins is the reverse of that in São Paulo. Lacking activities with revealed comparative advantages, these units of the federation had more options for diversification gains. In addition, some sectors were overestimated because of the strength of certain dimensions of the scoring index, as in the case of coke and oil derivatives. When Brazilian and world imports are considered, the market opportunities dimension substantially increases the score for this activity in the states because of its share of total imports by value. In 2017, for example, world imports associated with this activity accounted for 8.5% of the total.[6]

The diversification proposal prepared supports the ECLAC interpretation. Above all, it highlights the need for change in the production structure in order to achieve a higher level of development. States with lower levels of complexity are encouraged to invest mainly in less ubiquitous and more diversified activities, in order to reduce the differences in technical progress within and between states.

IV. The effects of complexity on employment

1. Econometric tests

As Prebisch (1950) emphasizes, the industrialization of Latin America led to a considerable increase in the incomes of the region's countries. According to Prebisch (1950, p. 5), "the industrial employment of the unemployed, or ill-employed, has thus meant a considerable improvement in productivity and, consequently, where other factors have not brought about a general lowering of productive efficiency, a net increase in national income".

Fixed effects models derived from a 2006–2015 panel database were used to estimate the effect of complexity on employment in Brazil. The commodity boom in this period reoriented economic activity in the country towards the primary sector. The result is an underestimation of the effect of complexity on job creation in Brazil in this period, as primary sectors are less complex. The period was selected, however, to furnish a larger number of observations for estimating the panel model.

As a control, we introduced the gross domestic product (GDP) figures provided for each state by the Brazilian Institute of Geography and Statistics (IBGE), deflated by the GDP deflator with 2010 as the base year. The interaction between the ECI and GDP was also considered in the regressions. As mentioned above, more complex regions have higher incomes. It is thus important to check the impact of this interaction on employment (emp). Lastly, two additional controls (X) were used: the logarithms of population (IBGE) and industrial employment (RAIS) in each state.

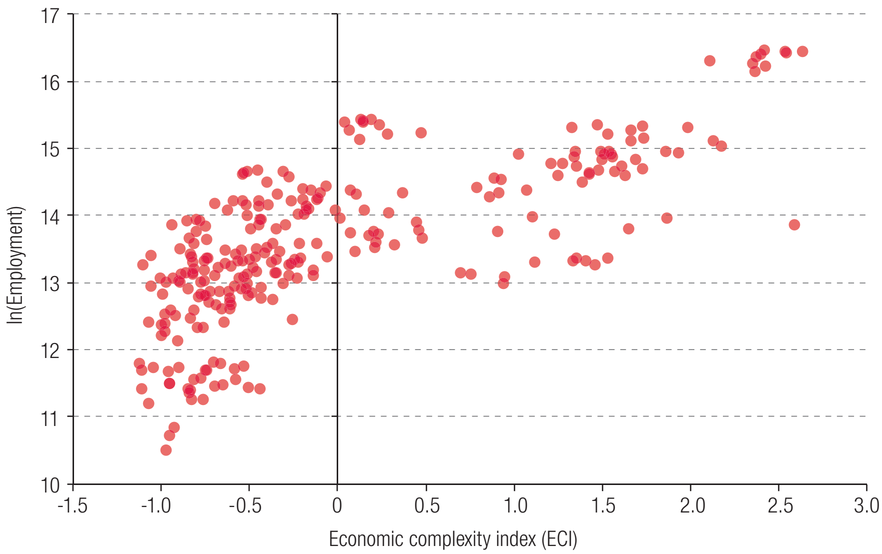
The equation estimated is therefore as follows:

$$ln\left(Emp_{it}\right) = \beta_0 + \beta_1 \cdot ECI_{it} + \beta_2 \cdot ln\left(GDP_{it}\right) + \beta_3 ECI_{it} \cdot ln\left(GDP_{it}\right) + \beta_i \cdot X_{it} + \varepsilon_{it} \quad (13)$$

The correlation between the variables of interest is shown in figure 1. The relationship between ECI and employment is positive, with a correlation level of 0.69. However, the points are distributed in a dispersed manner and the trend between these variables is not as similar.

[6] The figure is for activity 27, using the two-digit HS 2007 classification. The source is the COMEX STAT platform of the Ministry of Development, Industry and Trade.

Figure 1
Brazil: relationship between the economic complexity index (ECI) and employment, 2006–2015



Source: Prepared by the authors.

Table 4 presents the results of the regressions. Model i details the result of the model estimated using only the ECI and the state's real GDP. The results indicate that state GDP has a positive and significant effect on employment, but the ECI does not. Model ii brings in the interaction between GDP and the ECI. Now, both the state's GDP and the ECI have an employment effect that is positive and significant at the 5% level. The interaction, in turn, has a negative and significant effect. This indicates that the ECI has a stronger influence in states with low GDP, while in states with higher GDP, the influence of complexity on the volume of employment is small. In model iii, population is introduced as an additional control. It has a positive sign and is significant at 10%. The other variables remain significant, but the coefficient of the ECI decreases. In model iv, industrial employment is introduced and population is removed. In this model, industrial employment has a positive sign and is significant at 5%. This indicates that an increase in industrial employment induces an increase in overall employment in each state. Crucially, the ECI remains significant, suggesting that the structural composition of the economy is important even when the effect of industrial employment is considered. In model v, population and industrial employment are included as controls. While population shows no significant effect on employment, the other variables maintain a 5% significance level. A reduction in the ECI coefficient is also observed. Lastly, it is interesting to note that the models explain about 90% of the variance of overall employment.

Table 4
Effects of complexity on employment

	Model i	Model ii	Model iii	Model iv	Model v
Economic complexity index (ECI)	0.003	0.718**	0.553**	0.544**	0.469**
	(0.013)	(0.201)	(0.126)	(0.189)	(0.154)
Ln of GDP	0.364***	0.343**	0.329**	0.267**	0.277**
	(0. 076)	(0.086)	(0.100)	(0.087)	(0.090)
ECI*Ln of GDP		-0.039**	-0.030**	-0.029**	-0.025**
		(0.011)	(0.007)	(0.011)	(0.009)
Ln of population			0.739*		0.542
			(0.320)		(0.264)

	Model i	Model ii	Model iii	Model iv	Model v
Ln of industrial employment				0.238**	0.176**
				(0.082)	(0.046)
Constant	6.894***	7.305***	-3.706	5.973**	-1.756
	(1.342)	(1.530)	(4.408)	(1.602)	(3.857)
Unit of the federation fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.891	0.895	0.907	0.907	0.913
Number of observations	270	270	270	270	270

Source: Prepared by the authors.
Note: The dependent variable is the logarithm of the volume of jobs. Robust standard errors are clustered by region (cluster correction) in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

Thus, in model iv it can be observed that both complexity (represented by the ECI) and the logarithms of GDP and industrial employment present positive and significant effects. When population is introduced in model v, this variable does not show statistical significance. It was therefore decided to adopt model iv, in which all the variables considered were significant, as a benchmark.

One of the objectives of this section is to measure the relationship between complexity and employment, and the following equation, based on (13), defines the average marginal effect of the ECI on employment:

$$\frac{\partial \, ln\left(Employment\right)}{\partial ECI} = \beta_1 + \beta_3 \cdot ln\left(GDP\right) \tag{14}$$

Therefore, the average marginal impact of the ECI on the variance of employment is 0.017. In other words, a one-unit increase in the ECI generates an increase of about 0.017% in employment. Similarly, the average marginal effect of GDP on the variance of employment is 0.27.

By using the estimate of the average impact of complexity on employment, it was possible to simulate the impact of the acquisition of competitiveness in the sectors identified in section III on changes in employment, taking the 2010 production structure as a basis. To do this, it was assumed that the states would come to have revealed comparative advantages in the activities proposed, and the ECI was recalculated accordingly. To find the new value of the ECI, however, the indices were not calculated together, but separately. Since this indicator is related to the structure of all the other states, the index does not necessarily increase when it is calculated jointly, since it depends interactively on the results for the other states. Accordingly, the ECI calculated after the proposal is treated as the change caused by the average impact (0.017) if the ECI remained constant for all the states, i.e., if only the unit of the federation being considered were to adopt the diversification strategy featured.

2. Simulations

Once the change in the ECI had been calculated, going by the average effect on the logarithm of employment, it was possible to find the change in employment caused by the acquisition of revealed comparative advantages in the sectors considered promising. The estimation results are presented in table 5. Column (i) presents the initial complexity, and column (ii) presents the index once the three activities considered promising are being carried out competitively (revealed comparative advantage greater than 1). Column (iii) shows the change in the index once the proposal has been implemented. In columns (iv) and (v), the process is similar: column (iv) shows the number of jobs initially and column (v) the number of jobs after the diversification gain. Column (vi) shows the change in jobs. Lastly, for comparison, column (vii) shows the change in jobs if there is a one-unit increase in the ECI.

Table 5
Brazil: simulation of the effects of complexity on employment

Unit of the federation	Economic complexity index (ECI)		Change in the ECI	Employment		Change in employment	Change in employment if the ECI increases by one unit
	Before the proposal	After the proposal		Before the proposal	After the proposal		
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
RR	-0.833	0.186	1.019	78 585	79 930	1 345	1 320
AP	-0.777	-0.236	0.541	108 191	109 174	983	1 817
AC	-0.743	-0.018	0.725	121 187	122 663	1 476	2 036
TO	-1.002	-0.735	0.267	238 955	240 027	1 072	4 014
PI	-0.780	-0.708	0.072	377 463	377 920	457	6 341
RO	-0.733	0.162	0.895	334 290	339 316	5 026	5 616
SE	-0.509	-0.364	0.145	369 579	370 479	900	6 208
AL	-1.005	-0.325	0.680	470 992	476 372	5 380	7 912
PB	-1.105	-0.552	0.553	579 504	584 887	5 383	9 735
RN	-0.281	-0.128	0.153	575 026	576 504	1 478	9 660
MA	-0.740	-0.491	0.249	636 625	639 288	2 663	10 694
MS	-0.479	-0.307	0.172	560 789	562 409	1 620	9 420
MT	-0.063	0.146	0.209	656 542	658 847	2 305	11 029
AM	1.457	1.615	0.158	575 739	577 267	1 528	9 672
CE	-0.166	0.330	0.496	1 325 792	1 336 839	11 047	22 271
PA	-0.806	-0.750	0.056	951 235	952 130	895	15 979
ES	0.473	0.512	0.039	860 421	860 985	564	14 454
PE	-0.123	-0.116	0.007	1 536 626	1 536 807	181	25 813
GO	-0.627	-0.463	0.164	1 313 641	1 317 260	3 619	22 067
FD	0.441	1.756	1.315	1 099 832	1 124 127	24 295	18 476
SC	1.384	1.416	0.032	1 969 654	1 970 713	1 059	33 087
BA	-0.281	-0.128	0.153	2 139 232	2 144 730	5 498	35 936
PR	1.682	1.727	0.045	2 783 715	2 785 819	2 104	46 762
RS	1.492	1.496	0.004	2 804 162	2 804 350	188	47 106
MG	0.235	0.286	0.051	4 646 891	4 650 872	3 981	78 061
RJ	1.524	1.681	0.157	4 080 082	4 090 843	10 761	68 539
SP	2.366	2.300	-0.066	12 873 605	12 859 332	-14 273	216 257

Source: Prepared by the authors.
Note: The states are Acre (AC), Alagoas (AL), Amapá (AP), Amazonas (AM), Bahia (BA), Ceará (CE), Espírito Santo (ES), Federal District (FD), Goiás (GO), Maranhão (MA), Mato Grosso (MT), Mato Grosso do Sul (MS), Minas Gerais (MG), Pará (PA), Paraíba (PB), Paraná (PR), Pernambuco (PE), Piauí (PI), Río de Janeiro (RJ), Rio Grande do Norte (RN), Rio Grande do Sul (RS), Rondônia (RO), Roraima (RR), São Paulo (SP), Santa Catarina (SC), Sergipe (SE) and Tocantins (TO).

The states where the diversification gain produced the most jobs were the Federal District, Ceará and Rio de Janeiro. Because these units of the federation have more jobs, the change in the ECI leads to a more than proportional increase in jobs there compared to other states where the change in the ECI is larger and the number of jobs smaller (such as Roraima and Rondônia). Thus, these three states alone were responsible between them for the creation of about 46,000 new jobs.

At the same time, the states where the ECI changed the least registered fewer new jobs. Leaving aside São Paulo, where employment changed negatively, Rio Grande do Sul and Pernambuco were the units of the federation where employment changed the least in response to the diversification proposal presented in the previous section. The ECI rose by 0.004 and 0.007 in these two states, resulting in the creation of just 188 and 181 additional jobs, respectively.

The only atypical case where the increase in activities with revealed comparative advantages led to a decrease in the ECI and employment was São Paulo. This occurred because the indices are calculated in relative terms across sectors and states. The sectors proposed for São Paulo (wearing apparel and garments, beverages and furniture) are not very complex. Thus, despite increasing the diversification of the state's production structure, these sectors contributed to higher average ubiquity, reducing the complexity of the state's economy. Ubiquity in São Paulo was 5.5 in 2010, and the average ubiquity of the three sectors indicated by the diversification rule for the state is 9. In this case, therefore, the diversification component did not outweigh the increased ubiquity, as it did in Rio Grande do Norte, the only other case in which the average ubiquity of the activities considered for specialization was higher than the state average.

Considering this, it is important to note that there are three main reasons for the problem in São Paulo. First, the decision criterion: the high degree of aggregation of activities in CNAE 2.0 means that when activities that already have revealed comparative advantages are removed and a maximum number of repetitions is stipulated, less complex activities end up being selected for São Paulo. Second, diversification, with three more sectors producing competitively, does not mitigate the effect of increased ubiquity. Third, the structural characteristics of the state of São Paulo necessitate public development policies very different from those required by the other units of the federation. In other words, the fact that this state has a high level of economic complexity and is highly diversified places it on a different level, giving it greater scope for modernization in activities where there are already revealed comparative advantages. These considerations should therefore be taken into account in future studies.

The results presented in this section indicate that, in addition to strongly influencing GDP (Hausmann and others, 2011; Romero and Silveira, 2019), complexity also has a considerable impact on the volume of jobs in the economy. As Hausmann, Hwang and Rodrik (2007) point out, specialization in different products leads to different economic growth outcomes and also influences job creation. This once again underlines the need to modify the production structure in order to raise the level of economic development of the states, as argued in classic ECLAC studies.

V. Final considerations

Following the structuralist conception of economic development and drawing on recent studies that have used complexity indicators to structure production diversification policies, this article has sought to use the economic complexity approach to identify promising sectors with a view to increasing employment and economic growth in the Brazilian states. First, the complexity methodology was adapted so that employment or occupational data could be used to calculate regional complexity indicators. Next, panel data models were used to estimate the impact of complexity on employment. Lastly, as a way of evaluating the proposal developed, we carried out simulations of the effects of the diversification proposals on employment in Brazilian states in the event that they were to start producing competitively in the activities concerned.

To begin with, we drew on the work of Hausmann, Santos and Obach (2017) and Romero and Freitas (2018) to formulate an indicator that could be used to develop a diversification proposal for the Brazilian states. Complexity indicators were calculated with employment data to produce a ranking of promising products. From this, it was possible to identify the three most promising activities for public policies to focus on with a view to incentivizing competitiveness gains in each unit of the federation, given its existing production structure. Because the activities in which each state had revealed comparative advantages were removed and a limit was set on the number of repetitions, the sectors identified for the most complex states ended up being of low complexity. This process was mainly due to the high level of aggregation of the CNAE 2.0 activities selected, which was partly responsible for the limitations of the research when it came to proposing strategies for São Paulo. The use of a lower level of aggregation for future studies would avoid this problem.

This research has also made it possible to estimate the impact of increased complexity on employment. On the basis of panel data for the period 2006–2015, it is estimated that the addition of one ECI unit generates an increase of 0.017% in employment. This average marginal effect depends on states specializing in products that increase their complexity. Accordingly, the goods to be prioritized in public policies must not only be consistent with domestic structural characteristics, but must increase diversification and reduce the average ubiquity of the units in the federation.

The average marginal impact calculation conducted as part of the model estimation made it possible to measure the increase in jobs in the event that the states followed the diversification proposal. We first calculated how much the ECI might rise as a result of the acquisition of revealed comparative advantages in new activities. From this new value, using the average ECI effect, it was feasible to calculate the change in the number of jobs in each state's labour market. In the aggregate, the simulations demonstrated the possibility of 81,000 additional new jobs. The proposal could have a particularly strong impact in certain states. The Federal District, Ceará and Rio de Janeiro would gain about 46,000 new jobs.

The analysis presented in this paper demonstrates the clear relationship between the structuralist approach of ECLAC and the results of the research based on the economic complexity method. According to the paper's findings, a state's level of complexity has major implications for the volume of employment. This indicates that competitive production in sectors that are more diversified and less ubiquitous, and that thus increase the complexity of the state concerned, is reflected in a higher volume of jobs and is a driver of economic development.

The methodology described in this paper is therefore an important tool for guiding development policies. The difficulties arising from the unwinding of the commodity boom, which drove the reprimarization of the Brazilian economy, underline the importance of implementing sound and effective industrial policies to accelerate structural change in developing economies and boost income and employment growth. While fiscal constraints are a major limitation on the design of diversification policies, instruments such as exemptions, subsidized credit with conditionalities and government procurement can be used to encourage the development of strategic sectors. However, it is crucial for these measures to be time-limited and governed by well-established rules, with a quid pro quo required in the form of higher productivity or exports.

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Annex A1

Table A1.1
Correspondence between version 2.0 of the National Classification of Economic Activities (CNAE 2.0) and the Harmonized Commodity Description and Coding System (HS 2007)

CNAE 2.0	HS 2007
Two digits	Two digits
10	02, 03, 04, 05, 11, 13, 15, 16, 17, 18, 19, 20, 21, 23
11	22
12	24
19	27
20	28, 29, 31, 32, 33, 34, 35, 36, 37, 38, 39
21	30
22	40
15	41, 42, 64
14	43, 61, 62, 65
16	44, 45, 46
17	47, 48
18	49
13	50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 63
32	66, 67, 92, 95, 96
23	68, 69, 70
24	71, 72, 73, 74, 75, 76, 78, 79, 80, 81
25	82, 83, 93
28	84
27	85
30	86, 88, 89
29	87
26	90, 91
31	94

Source: Prepared by the authors.