Masters Dissertation

Product Space Study in the State of Alagoas

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Maceió, Janeiro de 2021

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Dissertation presented in partial fulfillment of the requirements for the degree of Mestre of Programa de Pós-Graduação em Modelagem Computacional de Conhecimento do Instituto de Computação da Universidade Federal de Alagoas.

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PRODUCT SPACE STUDY IN THE STATE OF ALAGOAS

Dissertação submetida ao corpo docente do Programa de Pós-Graduação em Modelagem Computacional de Conhecimento da Universidade Federal de Alagoas e aprovada em 13 de JANEIRO de 2021.

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ABSTRACT

The objective of this study is twofold: First, it aims at analyzing and interpreting Brazilian products exportation from 1997 to 2019. Second, it seeks to reduce the scope to the Alagoas state – one of the nation's poorest states – to identify possible exportation growth opportunities. Thereby, the study was conducted by using the model Product Space, which can show us, through a network, if it is possible to industries produce new products from those already produced by them. After analyzing the Product Space, we concluded that Alagoas is not isolated in the network. Alagoas can grow its network by exporting more than 50 products, such as motor vehicles, chemical wood pulp, and passenger cars. Such growth can promote new public and private partnerships. Thus, new industries might be attracted and boost Alagoas economic growth.

Keywords: Product Space. Alagoas. Market basket.

Resumo

O objetivo deste estudo está dividido em dois: primeiro, visa analisar e interpretar as exportações de produtos brasileiros de 1997 a 2019. Segundo, visa reduzir o escopo ao estado de Alagoas - um dos estados mais pobres do país - para identificar possíveis oportunidades de crescimento nas exportações. Desse modo, o estudo foi realizado por meio do modelo *Product Space*, que pode nos mostrar, por meio de uma rede, se é possível às indústrias produzirem novos produtos a partir dos já produzidos por elas. Após analisar o *Product Space*, concluímos que Alagoas não está isolado na rede. Alagoas pode ampliar sua rede exportando mais de 50 produtos, como veículos automotores, celulose química e automóveis de passageiros. Tal crescimento pode promover novas parcerias públicas e privadas. Com isso, novas indústrias podem ser atraídas e impulsionar o crescimento econômico de Alagoas.

Palavras-chave: *Product Space*. Alagoas. Cesta de mercado.

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and finally, to UFAL.

Juliana Leal

“O mundo dá voltas”

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATION

Table of contents

1 Introduction

Trade plays a central role as one of the channels of interaction between countries for the constant exchange of information (Koka et al., 1999). Considering this, the international trade network has attracted the attention of researchers from various fields such as agronomics, technology, and especially in complex networks (Vidmer et al., 2015). Through international trade data, over the years, it is possible to extract information and, with them, make oriented policies to transform trade's future.

Commercial partnerships, according to the classical theory of economics (Smith, 1904), would always be beneficial to those involved because of the competitive advantage. According to this premise, each country has a product in greater quantity or quality, allowing the exchange of goods between countries and, consequently, making the region's economic activity grow. In dealing with different countries, the exporter can know new technologies and techniques that, in the future, can be implemented in its export system. As a result, the demand for new human resources increases, causing new job openings to emerge. In parallel, there is the possibility of increasing the country's GDP, since exports become larger than imports. When exports exceed imports, the balance of the trade balance is positive, becoming a surplus. On the other hand, when a country exports less than it imports, the trade balance is negative and the trade balance consequently becomes a deficit. Thus, we can conclude that the larger the exports, the more money enters the country, and, therefore, the higher the GDP(InfoMoney, 2006).

Economic development is a long and challenging process of structural transformation. These are large-scale changes as new and emerging sectors emerge as drivers of job creation and technological modernization (Piergiuseppe Fortunato & Vrolijk, 2015). One of the ways to achieve structural transformation, according to Piergiuseppe Fortunato & Vrolijk (2015), is through the gradual addition of more advanced or more sophisticated products in the production chain of the region. Also according to the author, this can be achieved through a simple methodology to identify potential sectors and goods where a country is most likely to be competitive, given its productive capabilities.

Boschma & Frenken (2011) argues that the technological relationship, known as cognitive distance, increases the transfer and sharing of knowledge of pre-existing regional activities to emerging industrial activities within regional borders. Evidence from case studies shows that new industries and technologies do not start from scratch but evolve from regional structures that provide skills and related assets (Boschma et al., 2013). Other studies show that pre-existing resources and capacities in the regions are often rejuvenated and re-implanted in new combinations that give rise to new growth paths in the regions (Neffke et al., 2011).

The structural information relevant to a transformation can be extracted through a model of the global trading system as a graph, where countries are represented as vertices and trade channels as links between these vertices. In this way, the global trading system can be examined from a topological point of view (Serrano & Boguñá, 2003).

1.1 Problem statement

Since exports have played a vital role in the development of countries, there is a need to understand how products produced by a country relate. Starting from this need, Hidalgo et al. (2007) created the model known as *Product Space*. He thought of international trade as having the shape of a network to understand better the emergence of new industries from products already produced by a particular region. Also, he started with the idea that the relationship between preexisting economic activities has an impact on the future direction of economic development.

Product Space demonstrates, through a network, how dense or disconnected the links between exported products are. According to Muneepeerakul et al. (2013), *Product Space* represents how different products relate to one another. In the network, each product is a node that is characterized by a specific set of links to the other nodes in the network (Colombelli et al., 2013). To build these connections, it is taken into account that each product holds a specific production process. The closer it is to another product on the network, the more similar the basic production properties will be. Thus, it will be easier to identify new products for production and export, since the primary resources for its realization are present in the product already produced by the company. For example, if a country "A" exports apples, it would be more likely that it would produce pears instead of cars because they have the same industrial and technological base.

Using this modeling tool, we sought to build the network of Brazil and Alagoas. With the Brazilian network, we can comprehend the scenario that Alagoas is inserted to and understand how the products relate and also identify opportunities for market expansion for Alagoas.

2 BACKGROUD AND RELATED WORK

Next, we introduce the concept of Product Space presented by Hidalgo et al. (2007). He assumes that there is a link between products, not just technology, as a statistic. The network formed with such links is based primarily on the concepts of RCA and proximity. These and other concepts used for the study of Product Space and their dynamics are detailed in this chapter.

We create a table with a " simplified world ", in which we can visualize the concepts that will be presented throughout this chapter. Table 2.1 presents fictitious data from country A, its states, from E1 to E9, and its exported products, sugarcane, oil, soy, fertilizers, and electronics. The total export value of each product for each state is also broken down. Its last column shows the per capita GDP values of each state. The values in the table are in the monetary unit. For example, State 1 (E1) exports 45 of sugarcane and 8 of soy, both in the monetary unit. Thus, E1 exports, in its entirety, 53 in the monetary unit. And as shown in the table, its GDP is 295.

State	Sugarcane	Oil	Soy	Fertilizers	Eletronics	Total exported	GDP per capita
E1	45	0	8	0	0	53	295
E2	80	0	53	50	0	183	383
E3	5	0	7	80	200	292	450
E4	0	200	0	0	0	200	405
E5	0	40	0	0	0	40	279
E6	5	0	50	8	10	73	306
E7	30	0	5	0	0	35	271
E8	100	0	67	0	0	167	377
E9	0	0	5	40	100	145	358
Country A	265	240	195	178	310	1188	x

Table 2.1 – Simplified model of country A, its states and products exported. The values are in monetary unit.

2.1 The *Product Space*

The development of export and import in the countries are continually changing, both concerning rates and the different directions of standardization of the trade operation. According to Lall (2000), some countries are thriving: they are rapidly expanding the exports and increasing their quality. To do so, they are shifting the export structure from low-tech, low-skilled, and labor-intensive products to high-tech and high-skill products. However, generally, for there to be a significant change, the only way is to undergo a structural transformation (Chang, 2011).

According to Felipe et al. (2010), structural transformation is the process by which countries change what they produce and how they do it. Another feature is that countries move from low production and low wage activities to high productivity and high wage activities. Still, according to the author, structural transformation is composed of three components: (i) change in the output structure, from relatively low productivity activities to high productivity; (ii) change in the structure of employees, typically shows a decline in agriculture; (iii) improvement and diversification of production and export.

Hidalgo et al. (2007), Hidalgo & Hausmann (2009) and Hausmann et al. (2005) argue that growth and development are the result of structural transformation. According to the authors, not all products have the same consequences for the country's development. As a result, developing countries face great difficulties as they try to shift their production structure to a more sophisticated product. The level of sophistication of the country's exports proves a good growth forecast: initial income control and countries with more sophisticated exports grow faster (Felipe et al., 2010). For developmental analysis and structural transformation, Hidalgo et al. (2007) developed the *Product Space*.

The concept that permeates the *Product space* can be understood through the following simple analogy: imagine a region where you can find trees and giraffes. A tree would be a product, a vast agglomeration of them would be a set of products, and the giraffes are the companies or countries that exploit these products. Let's say that giraffes can only walk a certain distance. If this distance between one tree and another is greater than the giraffes' ability to move, they will eventually be unable to survive. However, if this area is heterogeneous with more deserted and denser areas and with diversified and smaller distances between the trees, the giraffes will be able to reach a greater agglomeration of trees. That is, the further away (related to the production capacity) a product is from another product, the more difficult the locomotion of the companies/country and the growth of themselves through the exploration of new products.

The *Product space* demonstrates, through a network, how dense or disconnected the links between exported products are. Basically, according to Muneepeerakul et al. (2013), it represents how different products relate to each other. In the network, each product is a node that is characterized by a specific set of links to the other nodes in the network (Colombelli et al., 2013). Some nodes have several connections, forming a nucleus - with more sophisticated products and denser connections - and others with few connections, characterizing the periphery - with less sophisticated products and few connections between the rest of them, as shown in figure 2.1.

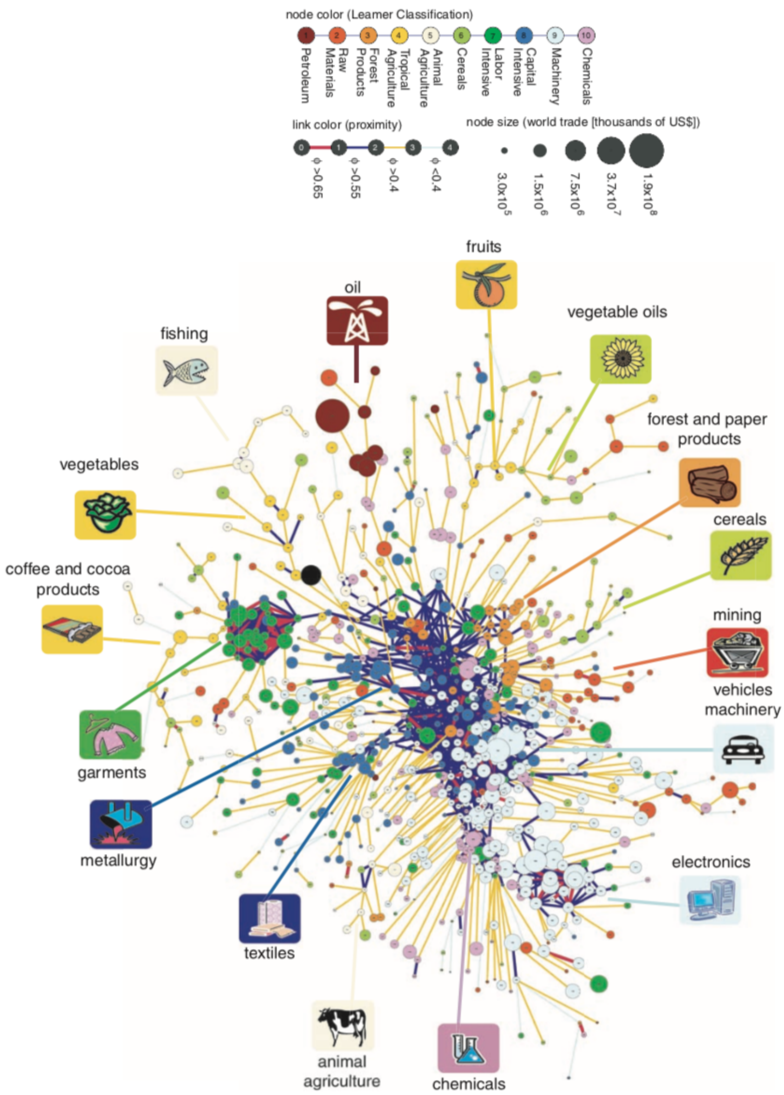


Figure 2.1 – Product Space representation by Hidalgo et al. (2007). The edges are colored according to the proximity value; the vertices colors are classified by Leamer's theory and their size is proportional to the world export value.

Figure 2.1 represents the worldwide *Product Space*. In the center of the network, we find more sophisticated products with a higher number of connections such as machinery, chemicals, and metal products. In its periphery are products that have little sophistication and, consequently, few connections such as animal agriculture, mining, and fishing.

In the representation attributed by Hidalgo et al. (2007), the circles are associated with each product and their diameters to the sales/export value of a given product. Its colors are linked to a set of specific products, such as chemicals, cereal, oil, which was determined by

Leamer (1985). The edges connecting the products are the designated proximities between each pair of products. Each color represents a specific range of proximity and the higher the value, the higher the possibility of producing and exporting that product, indicating that the country has the necessary skills and tools to expand its market.

In his paper, for the construction of the graph, Hidalgo et al. (2007) used the international database of *Feenstra, Lipsey, Deng, Ma, & Mo's "World Trade Flows: 1962-2000"* that consists the imports and exports from both the countries of origin and destination, using the products with *STIC* classification. *STIC* (Standard International Trade Classification) is a classification of goods used to classify the exports and imports of a country to allow comparison of different countries and years. This classification system is maintained by the United Nations with four digits.

To reach a network with all products, Hidalgo et al. (2007) used the Maximum Spanning Tree (MST). According to the author, this is nothing more but the tree containing a maximal sum of weights. In other words, it is the set of N-1 links (N being the number of nodes) that connect all nodes in the network and maximizes the sum of the proximities in it. Also according to the author, low proximity results in a crowded network, while one with high proximity obtains a sparse network. With that in mind, for a better visualization of the network, a certain threshold was chosen. Its best visualization was obtained when all links with proximity above 0.55 were maintained. This threshold generated a network with 775 nodes and 1525 links, which we can see in figure 2.1.

2.2 *Revealed Comparative Advantage* (RCA)

Based on the method of Hidalgo et al. (2007), the first step in constructing the *Product Space* network is the calculation of the *Revealed Comparative Advantage*, used to calculate product diversification. This factor captures the country's ability to be competitive on a larger scale of products (Felipe et al., 2010). *RCA* is a measure that informs whether a country's total export of a given product is greater or less than the total exported worldwide. *RCA* is the division between the market share that a country "c" holds of the product with the share of the product on the world market. Mathematically, according to Balassa (1986), *RCA* is given as follows:

$$RCA_{c,i} = \frac{x(c,i)/\sum_i x(c,i)}{\sum_c x(c,i)/\sum_{c,i} x(c,i)}, \tag{2.1}$$

where x (c, i) is the export value, in dollars, of the country *c* of the product *i*. A product is said to have *RCA* when *RCA* >1.

For example, we want to know if the export of soybeans from State 6 (E6) is relevant to the total exports of Country A. We can see in table 2.1 that E6 exported 50 dollars in soy and

Country A exported 195 dollars. The total of all products exported by State 6 is 306 dollars and Country A, 1188 dollars. Then, the equation of textit RCA looks like this:

$$RCA_{State6,soy} = \frac{50/195}{306/1188} = 4.17 \tag{2.2}$$

The rest of the results of the *RCAs* of the other products are listed in the table 2.2. The results of the equation, as long as it is greater than 1, indicates that the export of these products are significant in the Country A export.

Stado	Sugarcane	Oil	Soy	Fertilizes	Eletronics
E1	3,81	0,00	0,92	0,00	0,00
E2	1,96	0,00	1,76	1,82	0,00
E3	0,08	0,00	0,15	1,83	2,62
E4	0,00	4,95	0,00	0,00	0,00
E5	0,00	4,95	0,00	0,00	0,00
E6	0,31	0,00	4,17	0,73	0,52
E7	3,84	0,00	0,87	0,00	0,00
E8	2,68	0,00	2,44	0,00	0,00
E9	0,00	0,00	0,21	1,84	2,64

Table 2.2 – Revealed Competitive Advantage, through the equation 2.1, of the simplified world products proposed in the table 2.1.

2.3 Proximity

Some factors can be listed as responsible for the relationships among products, such as labor force, capital, technology sophistication, among others. For Hidalgo et al. (2007), these factors are few and far between. He then takes an agnostic approach based on the following idea: if two products are related by the same physical structures, technologies, similar institutions, or other characteristics, these products tend to be produced together, whereas products that have no similarities tend to be produced separately. According to the author, this idea is the proximity's denomination, which sums up the idea that the ability of a country to produce a product depends on the ability to produce other products. Given *RCA* as an identifier that a country is relevant in the world market for the export of a product, proximity (ϕ) is given by the minimum conditional probability between pairs in which a country exports the product i since it exports the product j. The conditional probability is given by $P(A|B) = P(A \cap B)/P(B)$. Then, proximity is formally defined by:

$$\phi_{i,j} = \min\left\{P(RCA_i|RCA_j), P(RCA_j|RCA_i)\right\} \tag{2.3}$$

The following equation gives the conditional probability between product *i* and *j*: the numerator of the equation is composed of the intersection between the two products, that is, how many states produce and export both products at the same time in question when they have *RCA*>1. For example, let's say we want to calculate the proximity between Soy and Sugarcane. According to the data from the Table 2.2, the states exporting Soy are E_2, E_6, E_8. The states that export Sugarcane are E_1, E_2, E_7, E_8.

Let *M(i)* be a function that returns the set of states that are relevant exporters of the product *i*. Thus, $P_{i,j}$ is given by:

$$P_{i,j} = \frac{|M(i) \cap M(j)|}{|M(j)|} \tag{2.4}$$

$$P_{soy,sugarcane} = \frac{|\{E_2,E_6,E_8\} \cap \{E_1,E_2,E_7,E_8\}|}{|\{E_1,E_2,E_7,E_8\}|}$$

$$P_{soy,sugarcane} = \frac{|\{E_2,E_8\}|}{|\{E_1,E_2,E_7,E_8\}|}$$

$$P_{soy,sugarcane} = \frac{2}{4} = 0.50$$

We do the same with $P_{cana,soja}$:

$$P_{sugarcane,soy} = \frac{|\{E_1,E_2,E_7,E_8\} \cap \{E_2,E_6,E_8\}|}{|\{E_2,E_6,E_8\}|}$$

$$P_{cana,soja} = \frac{|\{E_2,E_8\}|}{|\{E_2,E_6,E_8\}|}$$

$$P_{sugarcane,soy} = \frac{2}{3} = 0.66$$

Calculating the conditional probabilities, the proximity is the minimum of the pairwise between the two products:

$$\phi_{soy,sugarcane} = \min\left\{P(Soy|Sugarcane), P(Sugarcane|Soy)\right\}$$

$$\phi_{soy,sugarcane} = \min\{0.50, 0.66\} = 0{,}50$$

According to the result of the example above, the proximity between Soy and Cana is 0.50. This means that the two products have similar production processes. Therefore, the closer the proximity is to 1, the processes and production technologies are increasingly similar between the two products.

With the calculated proximities, it is possible to build the *Product Space* network. With it built, we can visualize how the products are located concerning other products according to their production properties. Taking into account that each product has a particular production process, the closer it is to another product in the network, they hold the same basic production properties. Thus, it will be easier to produce and export new products, since the primary resources for its realization are present in the product already produced by the company. Also, according to Hidalgo et al. (2007), even if a product already produced and exported by one company is far from another more sophisticated, the jump in the network would not be impossible. The company would require more effort in the implementation of policies to promote incentives and conditions to create the necessary basis for a more significant leap in the *Product Space* network.

2.4 Walking through the network

Possibilities for network jumps are essential for a region to be able to aggregate new products into its production basket. Such jumps are made more easily when products have equivalent sophistication. According to Hidalgo et al. (2007), there is a tendency for the regions to increase the *RCA* of products close to others that already have *RCA* developed.

Through a simulation, Hidalgo et al. (2007) proposed to clarify which products would be reached in future changes of production for possible increases in the productive chain. This simulation can show how the position of a region evolves when it is allowed to move repeatedly to other products with previously established proximity. According to the author, this property can be called diffusion.

For the diffusion simulation is selected a region of interest, a ϕ predefined proximity, and a number of interactions. Next, the products in the selected region interact with other products around it, and if the proximity between them is equal to or greater than ϕ, a new interaction is made from the new products reached and their neighbors. With this, we can predict which products have the possibility of being produced by the region.

The example of figure 2.2 may explain schematically the concepts of diffusion and interaction. As we can see, the graph has five nodes, corresponding to the products Cana, Oil, Soy, Fertilizers, and Electronics. The numbers in red refer to the proximity between them. Let's say that we want to diffuse State 7 (E7) with proximity equal to 0.5. In this scenario, this product can only spread to a product, the Soy product, with one interaction. The second interaction, with the same proximity, is part of the set of products reached by the first interaction. From Soy, the second interaction can not reach any product. In this situation, even if we increase the number of interactions, we would not be able to reach other products, since they have proximities below 0.5. Then, as we can see in the figure 2.2, it would be more likely to produce soy from the product already produced by the State 7.

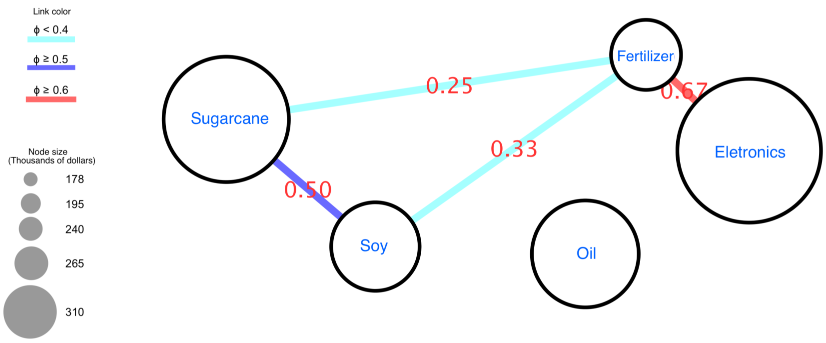


Figure 2.2 – Diffusion and interaton example.

2.5 PRODY

One of the factors that determine how complex the economy is and the power to explore new markets is the income level of a country. Countries tend to converge to the level of income dictated by the complexity of their productive chains, indicating that development efforts must focus on generating conditions that allow complexity to grow to generate sustainable growth and prosperity (Hidalgo & Hausmann, 2009). From this, it was found that there is a strong correlation between the position of the product in the *Product Space* and its value. Considering this, the author proposed a measure to summarize the position of each country in the network, given in two steps. First, he calculates the *PRODY*, tool developed by Hausmann et al. (2005). According to the author, this index is a weighted average of the GDP per capita of the countries that export a given product and therefore represents the level of income associated with that product. Still according to Hausmann et al. (2005), the *PRODY* of a product k is given by:

$$PRODY_k = \sum_j \frac{x_{(j,k)}/X_j}{\sum_j (x_{(j,k)}/X_j)} Y_j \tag{2.5}$$

in which Y_j is the per capita GDP of a country, j,$x_{(j,k)}$ is the total exported of the product k by country j, X_j is the export value of all products exported by country j and $\sum_j x_{(j,k)}/X_j$ is the sum of the numerator for all countries. With this value, we can consider that the more products with a high value of *PRODY*, the more prosperous the country or region that exports those products. For example, let's say we want to know the *PRODY* of Soy from the Table 2.1. The values of Y_j are listed in the Table 2.1. First we calculate $\sum_j x_{(j,k)}/X_j$:

$$\sum_j (x_{(j,k)}/X_j) = \frac{8}{53} + \frac{53}{183} + \frac{7}{292} + \frac{0}{200} + \frac{50}{73} + \frac{0}{40} + \frac{5}{35} + \frac{67}{167} + \frac{5}{145}$$

$$\sum_j (x_{(j,k)}/X_j) = 1.88$$

Then we start with the general formula:

$$PRODY_{soy} = \frac{8/53}{1.88} \cdot 295 + \frac{53/183}{1.88} \cdot 383 + \frac{7/292}{1.88} \cdot 450 + \frac{0/200}{1.88} \cdot 405 + \frac{50/73}{1.88} \cdot 279 + \frac{0/40}{1.88} \cdot 306 + \frac{5/35}{1.88} \cdot 271 + \frac{67/167}{1.88} \cdot 377 + \frac{5/145}{1.88} \cdot 358 \quad (2.6)$$

$$PRODY_{soy} = 345.22$$

The other calculated *PRODYs* values of the other products are listed in table 2.3.

x	PRODY
Sugarcane	319.44
Oil	342
Soy	345.22
Fertilizes	386.97
Eletronics	395.43

Table 2.3 – Simplified World Products *PRODYs*

The values of the *PRODYs* are compared to know which product has the most significant wealth. To have a forecast if the products reached in the diffusion simulation are considered rich and consequently will increase the wealth of the region that exports those products, the author makes an average of the *PRODYs* of the top *N* products after *M* interactions in given initial proximity (ϕ_0) and denoting it as:

$$< PRODY >^{N}_{M\phi_0} \quad (2.7)$$

For each round of interaction, the *PRODYs* of the *N* most valuable products of a given region are averaged. The products achieved by the diffusion taking into account predefined proximity are considered. Then they are placed in descending order and made another interaction. This process is done until it reaches the number of *M* interactions, previously defined. For example, let's say we want to know the progress of State 6, with *N* equal to 2, with one interaction and proximity equal to 0.2, 0.4, and 0.6. According to the table 2.2, State 6 only exports Soy. We can observe in the figure 2.2, for example, that, with 0.2, it can diffuse into the Sugarcane and Fertilizer products. For the PRODY calculation, we ordered the products reached with the diffusion in descending order of the PRODY value and we chose the top 2 products. The only two products with the highest PRODY are Sugarcane and Fertilizers. So, the example with 0.2 proximity would be:

$$< PRODY >^2_{1\phi_{0.2}} \tag{2.8}$$

$$< PRODY >^2_{1\phi_{0.2}} = \frac{319.44 + 386.97}{2}$$
$$< PRODY >^2_{1\phi_{0.2}} = 353.20$$

Increasing the proximity to 0.4, State 6 manages to diffuse only to a product, which would be Sugarcane. The average would be made with Sugarcane:

$$< PRODY >^2_{1\phi_{0.4}} \tag{2.9}$$

$$< PRODY >^2_{1\phi_{0.4}} = \frac{319.44}{1}$$
$$< PRODY >^2_{1\phi_{0.4}} = 319.44$$

When we evaluate the example with proximity 0.6, we notice that State 6 has no available paths to reach new products, because the closest proximity to another product is 0.5. In this case, State 6 comes to a situation that could no longer advance, hampering the growth of its industry.

With the interest of better understanding the economy and how the products relate, several authors sought to implement the tool proposed by Hidalgo et al. (2007) using different niche products and/or specific regions and some others proposed new models. These works can be seen in the next session.

2.6 Related work

Hidalgo et al. (2007) work is based on some previous work like Balassa (1986) and Hausmann & Klinger (2006). The first is the definition of the revealed competitive advantage formula (RCA). The second work portrays the motivation of using proximity, showing that in older theories, the Product Space network appears continuous and homogeneous implying that if a country can develop a product and move forward in the network, other countries will also be able to do so. The author demonstrates that with the use and study of proximity and other metrics such as *PRODY*, each region has different levels of development. Thus, the production chain and export enhancement depend on the heterogeneity in the network and on sufficiently close products, making this region capable of diffusing to the noblest part of the network.

Unlike Hidalgo et al. (2007), De La Cruz & Riker (2012) try to study the Brazilian export and its relation accurately, precisely, with the United States. Making a different approach presented in this paper, De La Cruz & Riker (2012) seek to identify which products could develop *RCA* within the Brazilian trade based on the distance between them, the country's resource constraints, and the extent of international competition. To do this, the authors follow the following steps: first, the Product Space network was built from 1998 to 2008 with exports from 121 countries. Then, another network with the data of 2008 is built, delimiting Brazil as the only country. With this network, the author seeks to estimate the probability of Brazil acquiring *RCA* on products that did not have *RCA* in 2008. As the last analysis, the authors seek to remodel the network with the products explicitly exported from Brazil to the United States.

With a global economy increasingly targeting a sustainable economy, some people with the power to learn about the economy may have a higher potential for the diversification and growth of their economies (Hamwey et al., 2013). Based on this, Hamwey et al. (2013) proposes to identify, through an analytical approach based on data, sustainable products, and sectors that a country is better positioned in the market for its production and export. Building on the Product Space network, the author analyzes a network built especially with sustainable products, allowing its analysis to help policymakers and others interested in identifying products in this growing niche. Besides, it would be possible to find out what policies are needed to support the production and development of products that promote and sustain social, environmental, and economic well-being.

Just like De La Cruz & Riker (2012) and (Hamwey et al., 2013) who sought to study different areas and niches from Hidalgo et al. (2007), Li et al. (2019) also sought to apply the *Product Space* into a specific area. Li et al. (2019) highlights the evolution of China's exports between 2000 and 2011. According to the author, China's export economy is shifting from a polarized structure to a relatively balanced system. Another author's finding is that China is moving from the peripheral products to products in the core in the network. China has developed a more diversified and balanced export basket, and gradually moved from periphery to core in the global *Product Space* (Li et al., 2019).

To analyze the technological base in 15 countries of the European Union regionally, Colombelli et al. (2013) applies a methodological framework based on Hidalgo et al. (2007) work. The author investigates whether the development of new technologies has some connection with the technologies already implemented in the region under study, considering the specific niche of nanotechnology. In this paper, Colombelli et al. (2013) adopts a differentiated methodology that replaces the *RCA* with a technology-based metric, Revealed Technology Advantage (RTA), which provides information about the strength or technological weakness of a given entity geographical area. One way to investigate the historical basis of new emerging technological bases, according to the author, is to calculate *RTA* for all technologies and to consider that the study region has a competitive advantage in these technologies if *RTA* is greater than 1.

Boschma et al. (2014) examines, through patent history, the relationship between technologies and how it changed 366 cities in the United States between 1981 and 2010. As in this paper, Boschma et al. (2014) seeks to show that cities tend to diversify into new technologies through existing technologies in the locality. Also, other parameters were used to reinforce its studies, such as the robustness analysis and concentration - average location through the number of patents. After analyzing the data, the author concluded that new technology is more likely to enter a city when it is technologically related to other already existing ones in the city. Existing technologies were more likely to leave the city when they had little or no relation to city technologies. According to Boschma et al. (2014), this result indicates that the relationships between technologies have been responsible for the technological change in the last 30 years in United States' cities.

In Qi et al. (2020)'s paper, they identify a list of marine-related products that have the greatest growth potential for 107 Chinese firms and their related industries and draw a conceptual model of marine-related products at the country and firm levels using the concepts of *Product Space* and product proximity. To do so, they made a *Product Space* network for China and the 107 Chinese firms from 2011 and 2012. After that, they calculated the maximum proximity of each marine-related product to products with high *RCA* values for each firm. The analysis in this paper proves that the marine-related products with the highest growth potential are the products that are very close to other products with high RCA values that are produced and exported by firms and that they are internationally competitive (Qi et al., 2020).

Some works are based on the definitions raised by (Hidalgo et al., 2007) and propose a new metric to present different forms of analysis referring to network complexity. Among these, Zaccaria et al. (2014) proposes a different way of building the Product Space network, called Taxonomy Network. This network intends to connect two nodes by the causality factor and not by their similarities, as presented in Hidalgo et al. (2007) work. According to Zaccaria et al. (2014), two products a and b will be connected not because they are similar, but if one of them, for example a, causes b to be more likely to be produced in the future, implying a direct link from a to b. It was proposed an algorithm that selects information present in the export data and from these data it was possible to build a hierarchical network in which nodes represent the products, and directed edges represent the relation between products. For Zaccaria et al. (2014), the differences between the Taxonomy Network and the Product Space are: (i) the presence of direct links, with the causality, clearly evidenced; (ii) the reduction in the number of links from order N^2 para N; (iii) the difference in standardization, which takes into account the diversification of countries. In its results, he composed a network of taxonomy in which the size of the vertices is proportional to the complexity of the product. The author concluded that a significant majority of products with high complexity appear in the periphery of the network while more basic products are in the nucleus, indicating that the centrality does not correspond directly to the complexity. This characteristic occurs precisely the opposite in the network presented by Hidalgo et al. (2007), in which the products with more complexity are in the core and the most basic in the periphery of the network. According to the author, this behavior is under the following hypothesis: the few capabilities required to produce products with low complexity represent the necessary condition to be able to produce products with high complexity.

Lebre de Freitas et al. (2015) also follows the referential base of Hidalgo et al. (2007). Focusing on Portugal, the author investigates which products produced by the site did not reach competitive advantage and are correlated to the region's standard of specialization. In this way, the author goes for a differentiated methodology in which it measures the relation between products with statistical analysis. He computes for each pair of products the Revealed Relatedness Index (RRI) defined as an increase in the likelihood that if a country owns a product with *RCA* is due to the fact that another product also contains *RCA*.

Needing to understand and improve competition in a particular group of companies, Delgado et al. (2015) seeks to study clusters and tries to offer a methodology that generates a set of information to meet the above need cited. In this way, the author creates an algorithm in which each configuration of a cluster is generated from specific parameters connected to industries that have similarities in its configuration. This algorithm provides scores that allow us to identify the configuration of the candidate that best captures various types of links between industries. With 51 clusters mapped in the United States, the author measures the links between industries from patterns of jobs co-location, establishments, and others. From this, it is possible to create a database with the clusters information of all of the country regions. Besides, it is also possible to raise the understanding of how to build new clusters by reducing internal barriers to trade and the improvement of technologies and thereby create possibilities for differentiation in the market.

Trying to outperform the index proposed by Hidalgo et al. (2007), Cicerone et al. (2020) managed to construct a new *Product Space Position* (PSP) index that is more suitable to handle regional and provincial data. Cicerone et al. (2020) adapt the *Product Space* to the Italian provinces and examines the extent to which network connectedness and centrality's export is related to its economic performance. According to the author, a part of the reason why is necessary to construct a new PSP index is related to the specialization discontinuities evident in the current indices which are inappropriate for capturing regional systems of innovation, and part of the reason is that the pure proximity-network dimensions of the current indices also insufficiently capture regional characteristics.

In Brazil, to contribute to the implementation of public policies, public and private investments, and to carry out academic work, the platform *Dataviva* was created[1]. Today, the website offers national data of the last ten years related to education, industry, economy, among other categories, all with the possibility of viewing by locality. This platform was developed by the Government of Minas Gerais in partnership with researchers from the MIT

[1]Available at http://dataviva.info.

Media Lab and uses the database provided by the Department of Labor and Social Security, Department of Development, Industry and Foreign Trade, and Department of Education. According to the website, providing free and open access to this information, provides more detailed knowledge of the Brazilian economy, generating inputs for planning and decision making by business people, students, investors, and professionals from any economic sector.

3 STUDY DESIGN

Some objectives were defined for the structure of this work. Primarily, construct, reproduce and interpret the network of Brazilan export products between 1997 and 2019. This way we can understand the Alagoas scenario. Secondly, process and interpret data from the Alagoan network to identify possible expansion points. That is, we intend to identify opportunities for growth through the Alagoas export network.

3.1 Research Questions

In order to meet the objectives of this work, we are guided by the following research questions.

RQ1: How did Product Space evolve in Brazil in the years 1997 to 2019?

With this RQ, we seek to understand how the Brazilian market works over the years 1997 to 2019. In addition, the answer to this RQ makes it possible to identify which are the main product niches in Brazil, if they have undergone changes, how the products relate, and visualize the general scenario of the Alagoas market.

RQ2: How could Alagoas advance in the Product Space?

With the Alagoas network study, it is possible to visualize which products are most susceptible to becoming new products for the production and export of the region. Considering this, it is possible to analyze the products already produced and exported by the state and, from them, indicate which products are most likely to be produced, increasing the range of opportunities for industries or companies that already exist in the state or for new industries interested in expanding their markets.

In the next session will be seen the methodology applied to elaborate this dissertation.

3.2 Study Phases

In the next sections, we will present the steps necessary to obtain the data and its use for the generation of the final results.

3.2.1 Data colection

We used data from *Sistema de Análise das Informações de Comércio Exterior* (Alice Web) [1]. All the database comes from Sistema Integrado de Comércio Exterior (SISCOMEX) which manages Brazilian foreign trade. In it, we can find the sales figures, in dollars, of all products exported by Brazil, States and Federal District annually. The search result can be sent via *e-mail* in *.xls* or *.txt* format.

For this paper, we used data from 1997 to 2019. The identification of each product is according to the Harmonized System Trade Code at the four-digit level (SH-4). The quantity of products analyzed refers to the totality exported by Brazil and each Brazilian state.

We can see in the figure 3.1 an example of a search done on the Alice Web site. The image refers to some products exported by Alagoas in the years 2016 and 2017. In the first column, we have the SH4 code. For each product described in the second column, an SH4 code is assigned. In the third column, we have the values, in dollars, in the period P1 (01/2017 to 12/2017) of each product exported in the year 2017. The fourth and fifth columns refer to the number of products sold, but they were not used in the scope in question. The other columns present the same previous definitions, but with data from period P2 (01/2016 to 12/2016) for the year 2016.

ALICEWEB - MINISTÉRIO DA INDÚSTRIA, COMÉRCIO EXTERIOR E SERVIÇOS
SECRETARIA DE COMÉRCIO EXTERIOR
EXPORTAÇÃO NCM BRASILEIRA

PARÂMETROS DA CONSULTA

UF: 27 - ALAGOAS
Primeiro detalhamento: Posição - SH 4 dígitos
Período P1: 01/2017 até 12/2017
Período P2: 01/2016 até 12/2016

		01/2017 até 12/2017			01/2016 até 12/2016		
Código SH4	Descrição do SH4	US$ de P1	Kg Líquido de P1	Quantidade de P1	US$ de P2	Kg Líquido de P2	Quantidade de P2
0401	Leite e nata, não concentrados nem adicionados de açúcar ou de outros edulcora	541	100	0	0	0	0
0402	Leite e nata, concentrados ou adicionados de açúcar ou de outros edulcorantes	5.583	538	0	0	0	0
0801	Cocos, castanha do Brasil e castanha de caju, frescos ou secos, mesmo sem cas	132.091	46.759	0	87.351	19.923	0
0904	Pimenta (do género Piper); pimentos dos géneros Capsicum ou Pimenta, secos	0	0	0	338.905	86.925	0
1102	Farinhas de cereais, exceto de trigo ou de mistura de trigo com centeio	1.113	1.500	0	0	0	0
1106	Farinhas, sêmolas e pós, de legumes de vagem secos da posição 0713, de sagu	5.286	1.468	0	2.017	574	0
1201	Soja, mesmo triturada	0	0	0	806.860	2.000.000	2.000
1211	Plantas, partes de plantas, sementes e frutos, das espécies utilizadas principalm	0	0	0	440	10	0
1513	Óleos de coco (óleo de copra), de palmiste ou de babaçu e respectivas fracções,	340.274	39.290	0	120.752	14.051	0
1517	Margarina; misturas ou preparações alimentícias de gorduras ou de óleos animai	1.237	41	0	0	0	0
1701	Açúcares de cana ou de beterraba e sacarose quimicamente pura, no estado sól	444.531.462	1.033.081.753	1.033.083	364.906.974	1.009.080.036	1.009.079
1702	Outros açúcares, incluídos a lactose, maltose, glicose e frutose (levulose), quimic	16.963	1.958	0	15.014	1.649	0
1703	Melaços resultantes da extracção ou refinação do açúcar	0	0	0	3.057.955	11.978.356	0
1905	Produtos de padaria, pastelaria ou da indústria de bolachas e biscoitos, mesmo a	446.350	240.904	0	713.710	347.440	0
2007	Doces, geleias, marmelades, purés e pastas de frutas, obtidos por cozimento, co	11.859	3.709	0	20.616	4.965	0
2008	Frutas e outras partes comestíveis de plantas, preparadas ou conservadas de ou	10.380	6.521	0	28.569	19.462	0
2009	Sumos de frutas (incluídos os mostos de uvas) ou de produtos hortícolas, não fer	675.488	314.003	0	534.328	247.085	0
2103	Preparações para molhos e molhos preparados; condimentos e temperos compo	45.472	3.187	0	21.940	1.684	0
2106	Preparações alimentícias não especificadas nem compreendidas noutras posiçõe	0	0	0	3.887	248	0
2207	Álcool etílico não desnaturado, com um teor alcoólico em volume igual ou superio	3.953.894	3.879.648	4.917.676	0	0	0
2208	Álcool etílico não desnaturado, com um teor alcoólico em volume inferior a 80 %	91	4	2	51	21	25

Figure 3.1 – Sample table acquired on *Alice Web* site.

[1] Alice Web was deactivated and replaced by Comex Stat in 2018. The data will be available on http://comexstat.mdic.gov.br/en/home.

However, the format provided by *Alice Web* is not suitable for the elaboration of the experiment. To do so, the data was processed for database creation. This procedure will be further explained in the next section.

In the next subsection, we present how the database was built. In the subsection 3.2.2 we show the process of data migration and in the following subsection 3.2.3 how the database is formed and how to make queries.

3.2.2 Database Creation and structure

As explained earlier, the format provided by Alice Web is not suitable for the experiment. Then, to facilitate the execution of the experiment, a relational database was created in *Mysql*. For its creation, the following steps were followed: we visit the Alice Web website and requested the *.xls* files by e-mail. Next, a set of *Python scripts* was written that process the data of the table in *.xls* from *Alice web*. After this processing, the data is imported into the *Mysql* database. This process is illustrated in figure 3.2.

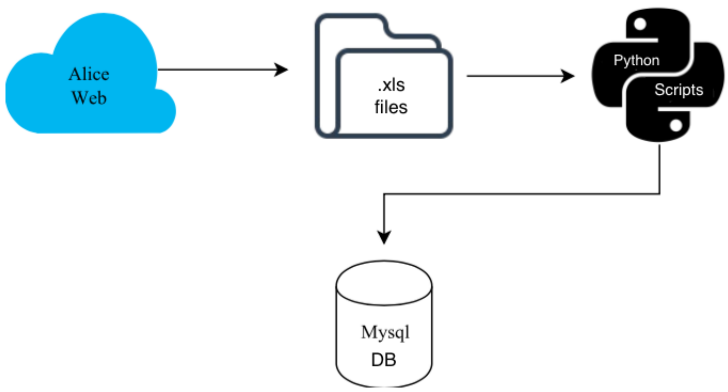


Figure 3.2 – *Alice Web*'s database transformation.

The result of the database model after the data transformation process will be explained in the following subsection.

3.2.3 Data model

All data were stored in a database referring to exports from Brazil and Alagoas, between 2010 to 2019. The model of this database is represented in figure 3.3.

Each box in the database model represents a table. The first table, *products*, contains all the codes from *Alice Web*. It consists of two columns:

- **cmdCode**: product code;
- **cmdDescE**: product description.

The *categories* table lists all codes and descriptions of the product category that we can find in *Alice Web* tables. Its columns are structured as follows:

- **cmdCode**: product ccode;
- **description**: category description;
- **cod**: category code.

The following table, *states*, stores the GDP per capita values for each state. Its columns are:

- **pib_per_capta**: GDP per capita of each state;
- **rtTitle**: state name.

The fourth table, *all_trades*, refers to transaction data for all Brazilian states. Its columns are formed by:

- **yr**: year of the product exportation;
- **rtCode**: state code;
- **rtTitle**: state name;
- **cmdCode**: product code;
- **TradeValue**: how much, in the dollar, the product was sold;
- **cmdDescE**: product description;
- **RCA**: *RCA* of the product (subsection 2.2).

The *proximity* table stores the values of proximity between product *i* and product *j* (subsection 2.3). It is presented as follows:

- **product_i**: product *i* code;
- **product_j**: product *j* code;
- **proximity**: proximity value;
- **yr**: year of the product exportation.

The *diffusion* table aggregates the diffusion values into all its interaction steps (subsection 2.4). Its columns are:

- **rtCode**: state code;
- **cmdCode**: product code;
- **iteraction**: number of interactions;
- **threshold**: definition of the proximity's limit for a given interaction.

prody represents the table with the *PRODYs* values of all exported products (subsection 2.5). Its columns are formed by:

- **cmdCode**: product code;
- **yr**: year of the product exportation;
- **prody**: *PRODY* value of each state.

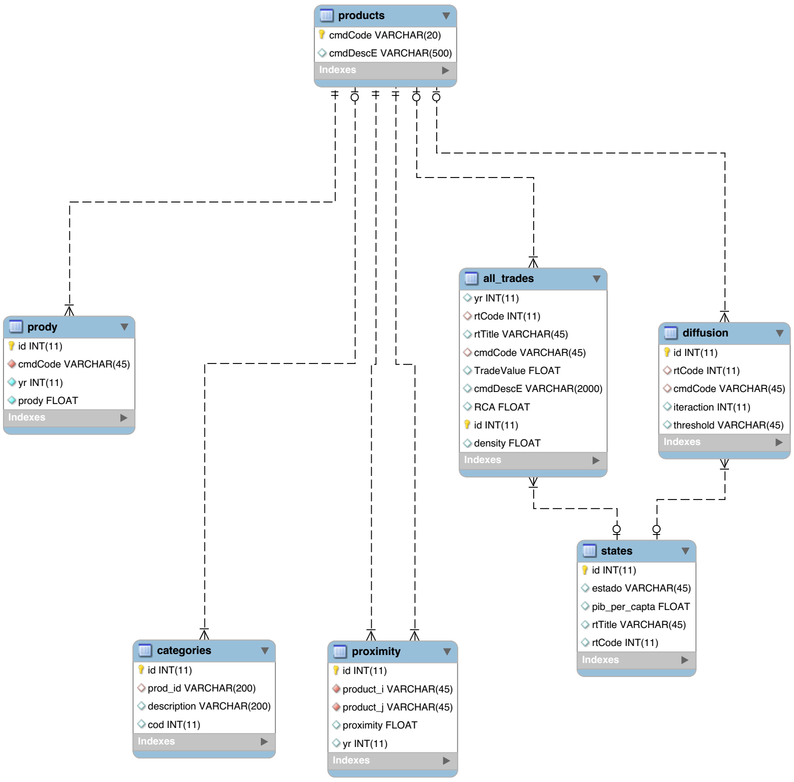


Figure 3.3 – Model of the database.

This database is available at https://zenodo.org/record/4247853.

With the complete database, we can construct queries to facilitate the execution of the experiment. For example, let's say we want to know the exporter of the product to Alagoas with *RCA*>1 in 2017. In the database, the search would look like this:

*select * from all_trades where rtCode = 2 and RCA> 1 and yr = 2017*

The database returns a table with the columns that were requested in this search. Visually, results are presented as in figure 3.4.

Tabela 1

yr	rtCode	rtTitle	cmdCode	TradeValue	cmdDescE	RCA	id
2017	2	Alagoas	1513	340274	Óleos de coco (óleo de copra), de palmiste ou de babaçu e respectivas fracções, mesmo refinados, mas não quimicamente modificados	24.7014	617448
2017	2	Alagoas	1701	444531000	Açúcares de cana ou de beterraba e sacarose quimicamente pura, no estado sólido	12.7541	617452
2017	2	Alagoas	1905	446350	Produtos de padaria, pastelaria ou da indústria de bolachas e biscoitos, mesmo adicionados de cacau; hóstias, cápsulas vazias para medicai	1.2272	617458
2017	2	Alagoas	2207	3953890	Álcool etílico não desnaturado, com um teor alcoólico em volume igual ou superior a 80 % vol; álcool etílico e aguardentes, desnaturados, co	1.60448	617470
2017	2	Alagoas	2403	835969	Outros produtos de tabaco e seus sucedâneos, manufaturados; tabaco homogeneizado ou reconstituído; extratos e molhos de tabaco	3.50722	617476
2017	2	Alagoas	2505	17992	Areias naturais de qualquer espécie, mesmo coradas, exceto areias metalíferas do Capítulo 26	2.71868	617478
2017	2	Alagoas	2515	28260	Mármores, travertinos, granitos belgas e outras pedras calcárias de cantaria ou de construção, de densidade aparente igual ou superior a 2,5	1.54775	617480
2017	2	Alagoas	2815	4886060	Hidróxido de sódio (soda cáustica); hidróxido de potássio (potassa cáustica); peróxidos de sódio ou de potássio	72.0897	617484
2017	2	Alagoas	3904	23815700	Polímeros de cloreto de vinilo ou de outras olefinas halogenadas, em formas primárias	63.0441	617498
2017	2	Alagoas	3916	260705	Monofilamentos cuja maior dimensão do corte transversal seja superior a 1 mm (monofios), varas, bastões e perfis, mesmo trabalhados à sup	3.33752	617500
2017	2	Alagoas	4015	85805	Vestuário e seus acessórios (incluídas as luvas, mitenes e semelhantes), de borracha vulcanizada não endurecida, para quaisquer usos	7.84403	617514
2017	2	Alagoas	6907	4620350	Ladrilhos e placas (lajes), para pavimentação ou revestimento, não vidrados nem esmaltados, de cerâmica; cubos, pastilhas e artigos semelh	4.45529	617538
2017	2	Alagoas	7117	54448	Bijutarias	1.82402	617542
2017	2	Alagoas	7404	913557	Desperdícios e resíduos, de cobre	4.68783	617550
2017	2	Alagoas	7602	323390	Desperdícios e resíduos, de alumínio	6.21165	617552
2017	2	Alagoas	8421	171657000	Centrifugadores, incluídos os secadores centrífugos, aparelhos para filtrar ou depurar líquidos ou gases	139023	617562
2017	2	Alagoas	8454	25500	Conversores, cadinhos ou colheres de fundição, lingoteiras e máquinas de vazar (moldar), para metalurgia, aciaria ou fundição	5.92079	617572
2017	2	Alagoas	8903	838000	Iates e outros barcos e embarcações de recreio ou de desporto; barcos a remos e canoas	14.4255	617590

Figure 3.4 – Example of query result in the database.

From the database, we can request information as shown in the figures 3.5 e 3.6. In the first, we have all categories of products sold by Brazil, how much in dollars was exported in some predefined years. In the second figure, we can see the categories of products sold by Alagoas, the number of products sold in each category in some predefined years. In the database, we can request all this information of the two figures, besides all Brazilian states and all years between 1997 and 2019. Also in the database, we find all the proximity between each product, which are necessary for the production, for example, of graph 4.1; the *prody* as shown in figure 4.8; the diffusion rounds, as shown in figures 4.9 e 4.10.

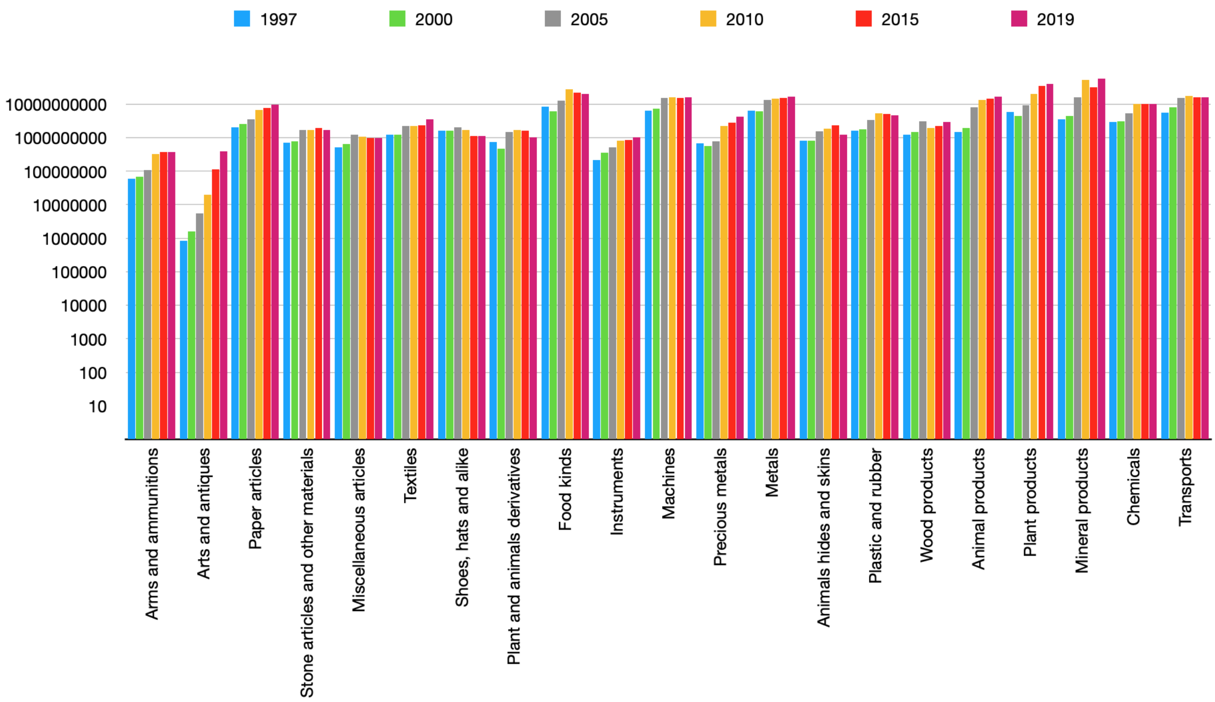


Figure 3.5 – Quantity in dollars of products exported by category in the years 1997, 2000, 2005, 2010, 2015, and 2019 in Brazil. The y-axis is on a logarithmic scale.

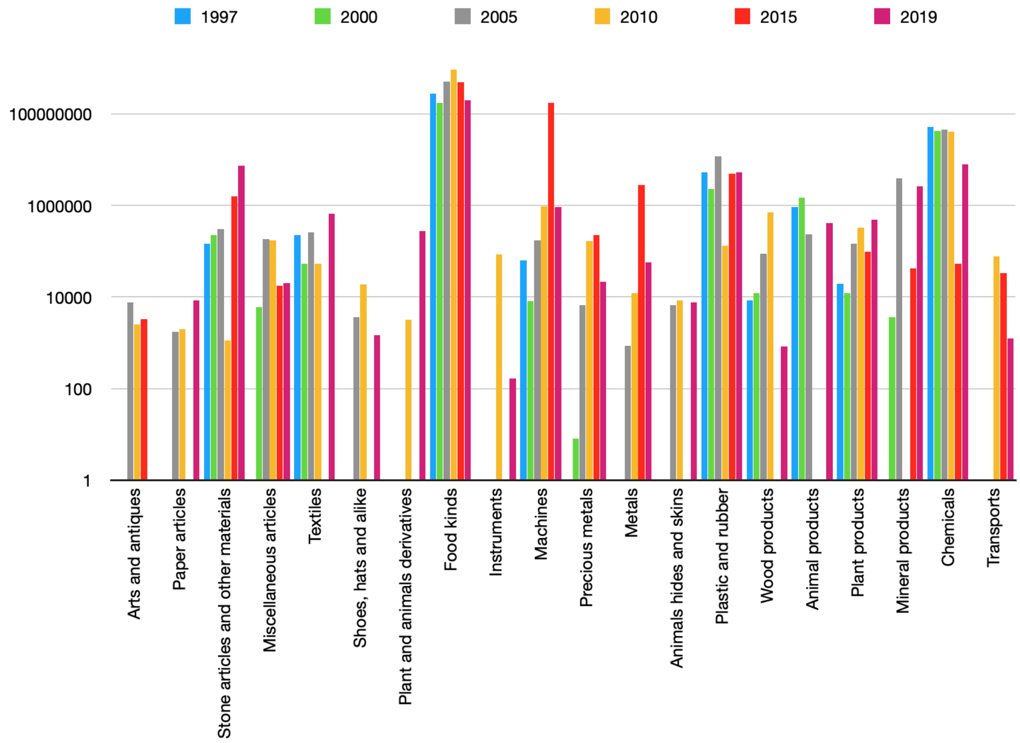


Figure 3.6 – Quantity of products exported by category in the years 1997, 2000, 2005, 2010, 2015, and 2019 in Alagoas. The y-axis is on a logarithmic scale.

3.2.4 *RCA*, proximity and *PRODY* computation

For calculation of the *RCA* (see Section 2.2), proximity (see Section 2.2) and *PRODY* (see Section 2.3), we made scripts that make use of the database. The scripts' results are stored in the database in the following tables: *all_trades*, *proximity* e *prody*, and more precisely in the columns *RCA*, *proximity* and *prody*, respectively.

3.2.5 Graph Generation

With the proximity pairs defined, we set out for the visual construction of the graph. To do this, we use the Cytoscape tool version 3.4.0. It is possible to insert a spreadsheet containing all the product pairs and their respective proximity. With this worksheet, Cytoscape can generate a graph in which the nodes are represented by the products and the edges, the proximities. For the classification of products by categories, we consulted dataviva.info and, for the distinction of each product category, a specific color was defined.

4 RESULTS AND DISCUSSIONS

4.1 RQ1: How did Product Space evolve in Brazil in the years 1997 to 2019?

The best understanding of the Product Space network is a method for ascertaining the growth of the market because with it we can observe the position of a given region in the network. Also, we can analyze how this region behaves over the years and interpret the scenario that Alagoas is inserted. Having this in mind, this work tries to answer the RQ1.

One of the ways to answer the above question was the construction of six graphs that show the behavior of the Product Space network in the years 1997 to 2109. Through these graphs, it is possible to extract data regarding the interaction that occurs between the products, how they behave, and which product has a greater potential to be produced by the analyzed region.

As we see in Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6, some changes are observable. Firstly, comparing the figures, it is visible the increase in the number of products in the network in 2019, forming a larger and concise cluster in its central part. Also, we can observe the formation of a small core with products with strong connections near the center of the network while the core of the other's network is more sparse. That is the main difference between the visual aspect in the graph produced by Hidalgo et al. (2007) and the Brazilian network. While the network presented by the author is fully connected, the Brazilian network presents some clusters of products completely independent and without any connection with the rest of the network.

Although visually present changes, most of the set of products exported by Brazil remains the same, with almost negligible changes among the years studied. In its initial network, in 1997, Brazil exported 1,101 products. In 2000, 2005 and 2010, it had, respectively, 1,102, 1,147 and 1,141 products. By 2015, the country had 1,147 products and in 2019, 1,157 products. Even though the number of products increased, especially between the years 2000-2005 and 2015-2017, the number of links between them decreased. These links decreased from 50,729 in 1997 to 36,706 in 2019. Although the links between the products have decreased among the years shown in the figures cited above, it is notable the increase of stronger bonds (forming concise clusters) which can show that the Brazilian market is specializing in certain products and, thus, creating a technological and professional base for the entry of new products.

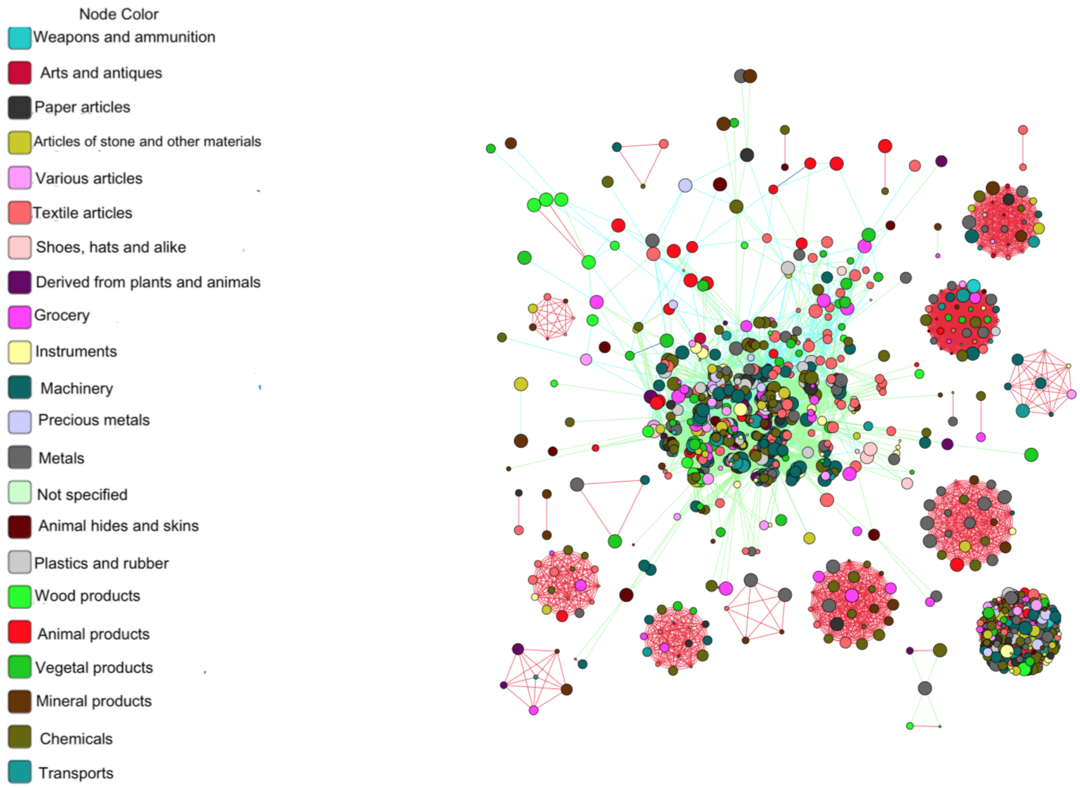


Figure 4.1 – Represents the Brazil product network in 1997. The vertices colors represent the various product categories (which is described in the column on the left) and those of the edge - light blue, green, dark blue, and red - represent, respectively, the proximity of 0 to 0.65, 0.66 to 0.75, 0.76 to 0.85 and 0.86 to 1.

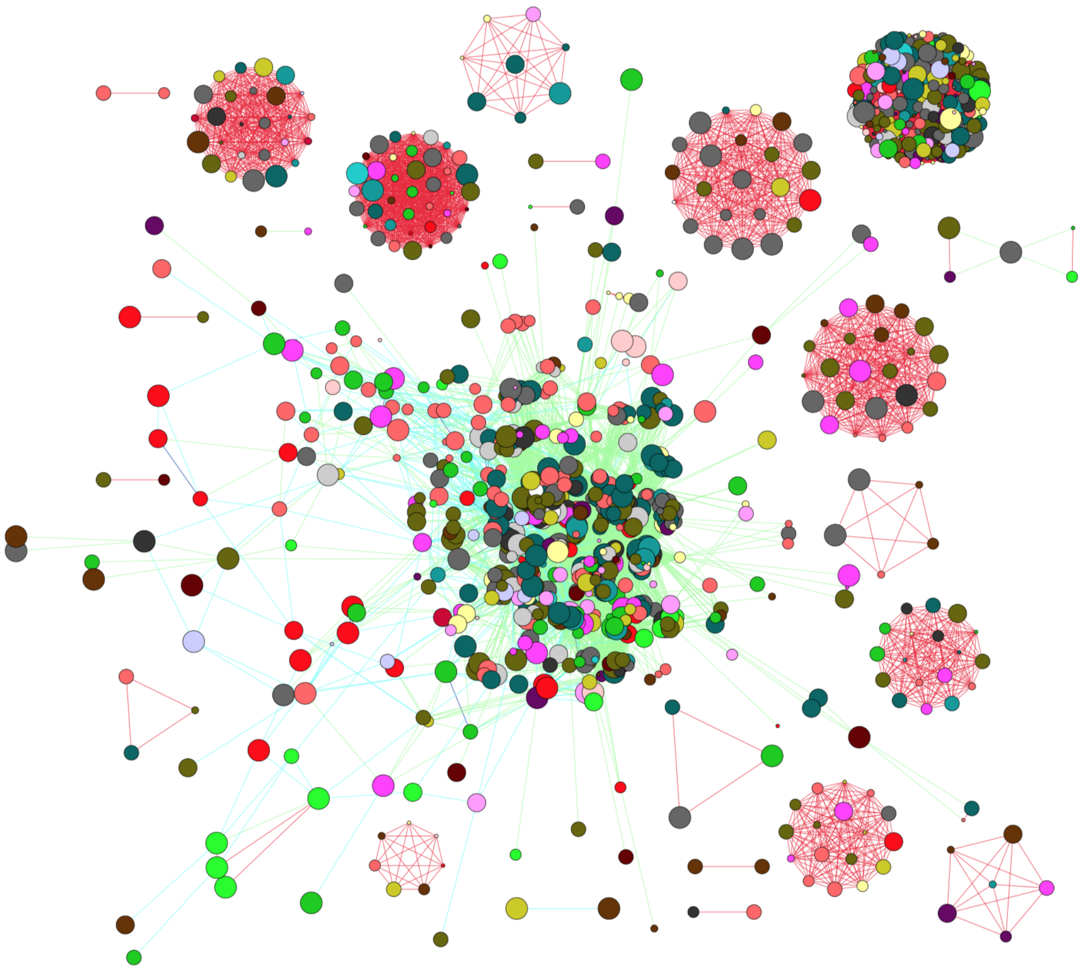


Figure 4.2 – Represents the Brazil product network in 2000. The vertices colors represent the various product categories and those of the edge - light blue, green, dark blue, and red - represent, respectively, the proximity of 0 to 0.65, 0.66 to 0.75, 0.76 to 0.85, and 0.86 to 1.

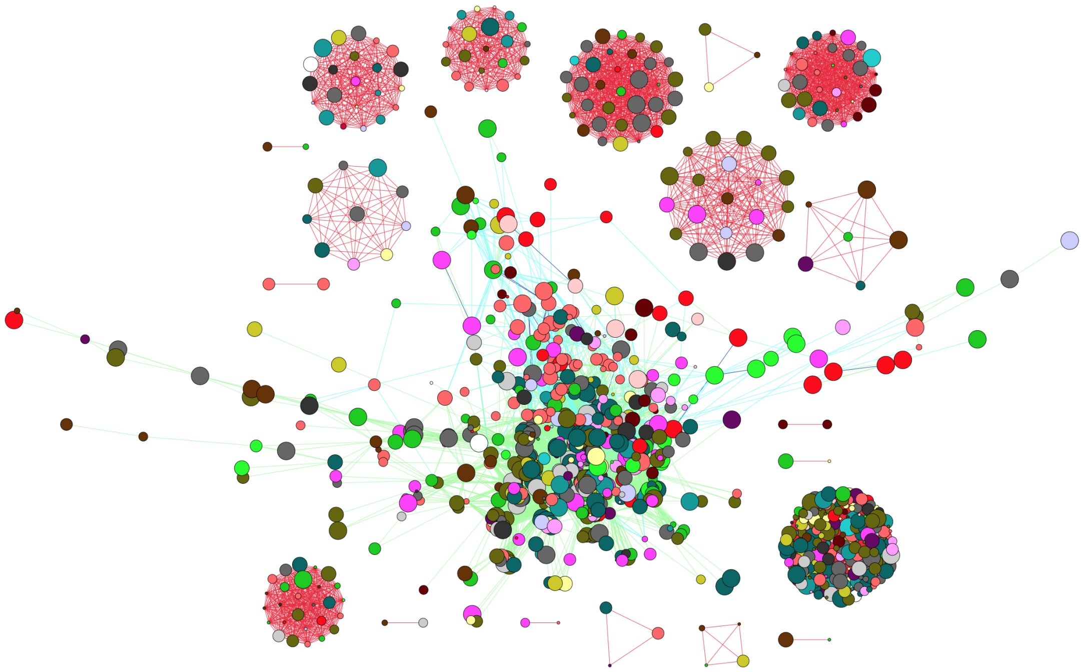


Figure 4.3 – Represents the Brazil product network in 2005. The vertices colors represent the various product categories and those of the edge - light blue, green, dark blue, and red - represent, respectively, the proximity of 0 to 0.65, 0.66 to 0.75, 0.76 to 0.85, and 0.86 to 1.

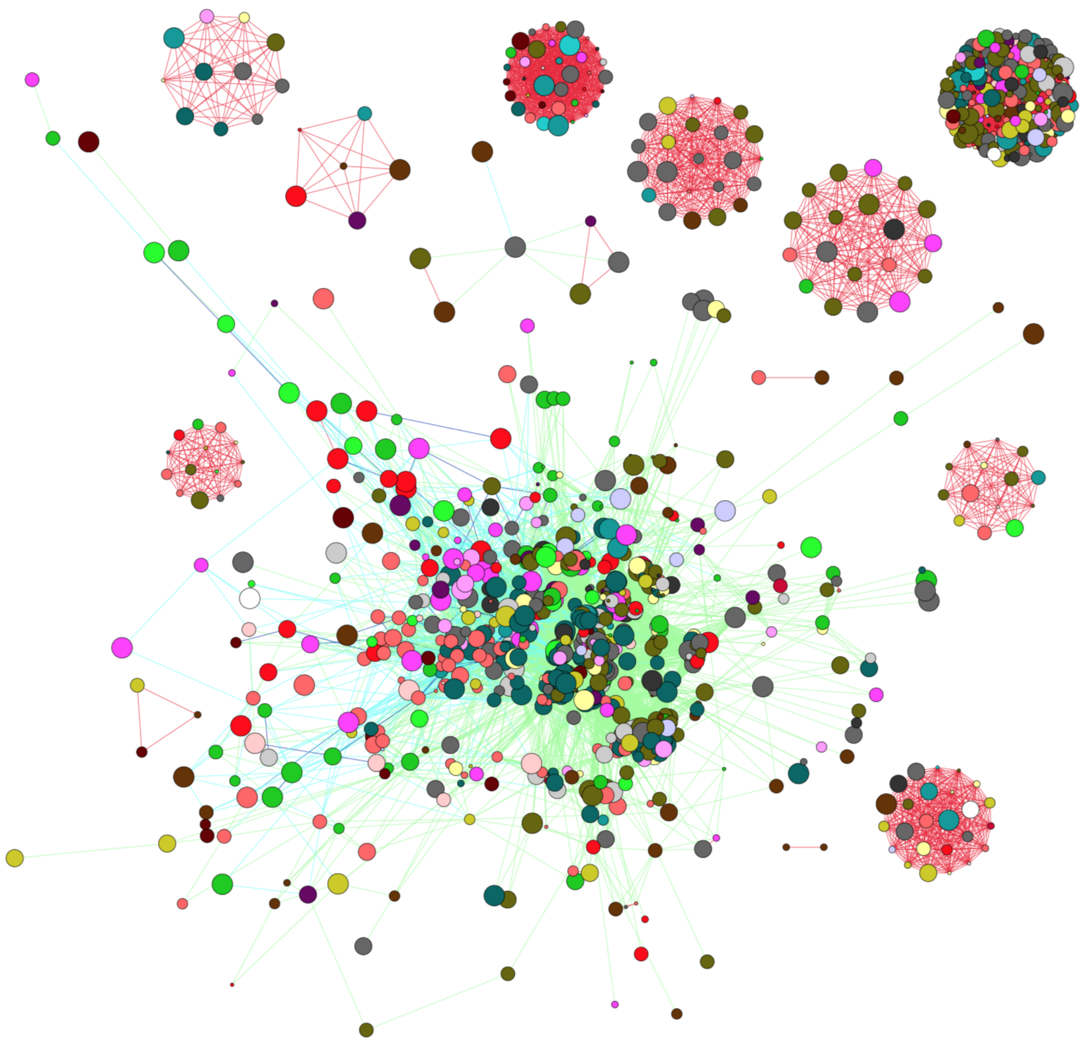


Figure 4.4 – Represents the Brazil product network in 2010. The vertices colors represent the various product categories and those of the edge - light blue, green, dark blue, and red - represent, respectively, the proximity of 0 to 0.65, 0.66 to 0.75, 0.76 to 0.85, and 0.86 to 1.

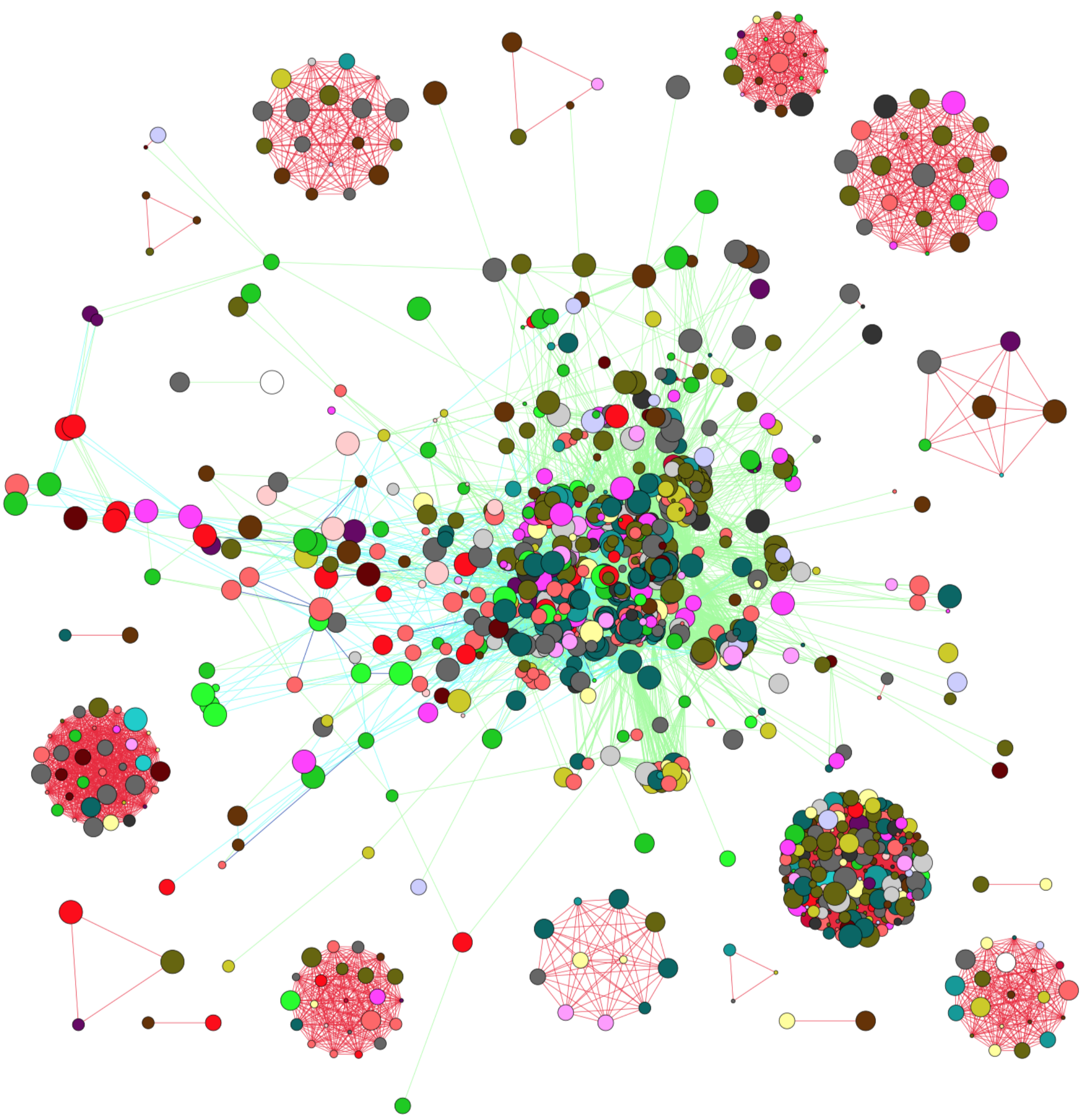


Figure 4.5 – Represents the Brazil product network in 2015. The vertices colors represent the various product categories and those of the edge - light blue, green, dark blue, and red - represent, respectively, the proximity of 0 to 0.65, 0.66 to 0.75, 0.76 to 0.85, and 0.86 to 1.

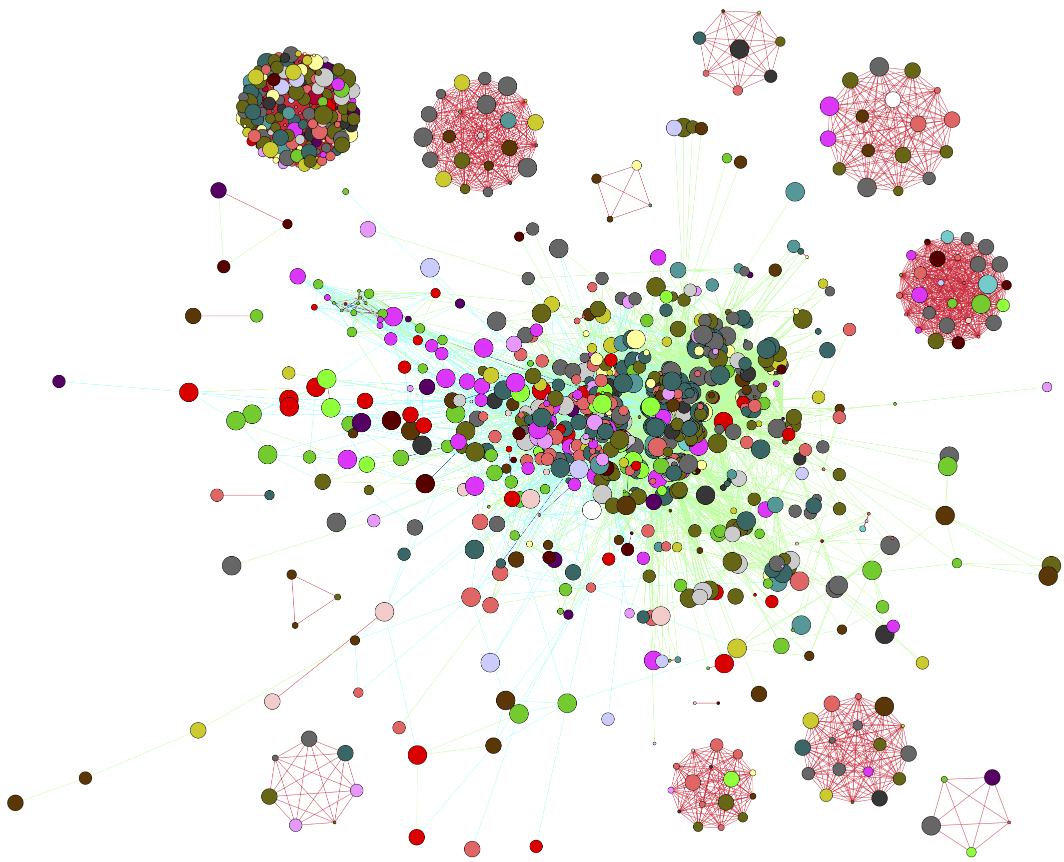


Figure 4.6 – Represents the Brazil product network in 2019. The vertices colors represent the various product categories and those of the edge - light blue, green, dark blue, and red - represent, respectively, the proximity of 0 to 0.65, 0.66 to 0.75, 0.76 to 0.85, and 0.86 to 1.

Another way of visualizing how the country behaves concerning exports is through the 4.7 chart. In it, we have the most sold products in exports in Brazil between the years 1997 and 2019. One aspect that we can see is that Corn took fourth place in 2019, making Cane decline two positions. The products majority, as we can see in the description of the table 4.1, show that Brazil is a predominantly exporter of raw materials, such as meats, soy, metals, among others. This may lead to the conclusion that the country is a little distant to become a developed country since they import raw material while underdeveloped countries are focused on exporting them. With the growth of corn exports, it can show that Brazil still has a strong presence in the economy of underdeveloped countries. Such positioning provides products to developed countries for the transformation of these resources into commodities for consumption. Besides, most products remain practically constant between the recent years of 2010, 2015, and 2019, which demonstrate an economic and production balance in the country.

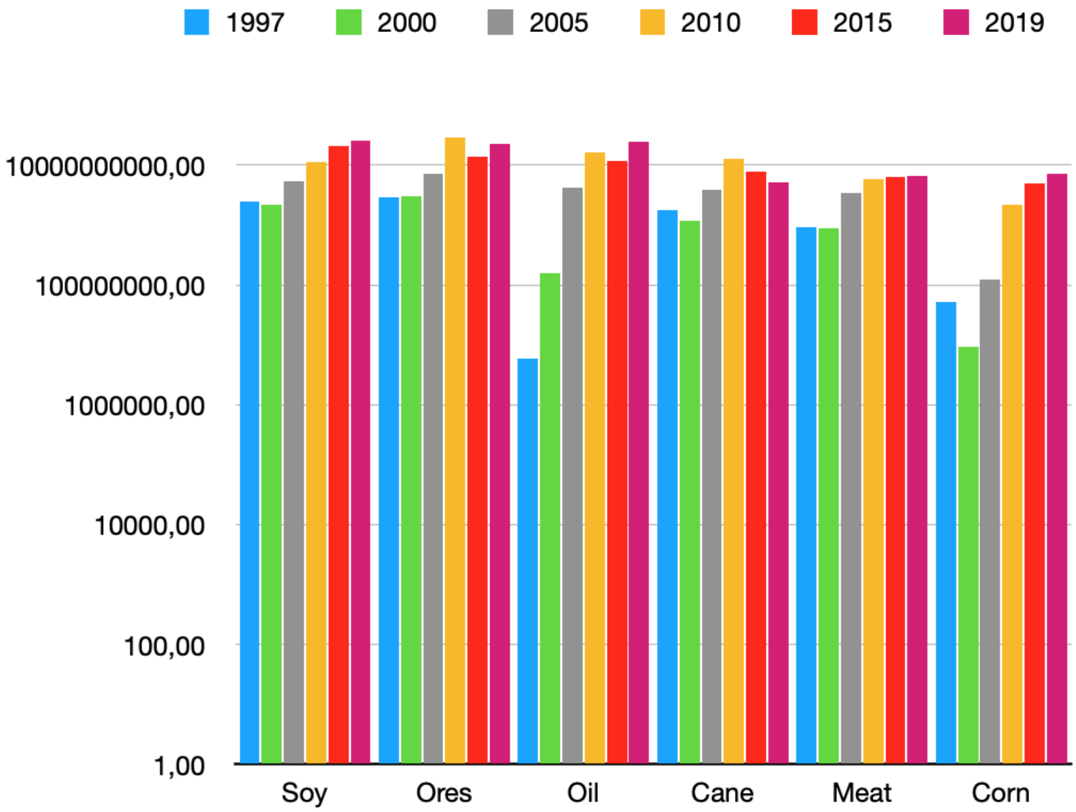


Figure 4.7 – Export of the 5 products with the highest dollar exports in Brazil between 1997, 2000, 2005, 2010, 2015, and 2019. The exception of Corn, in 2019, which came in fourth place, taking the position of Cane. Names and product codes can be seen in table 4.1. The y-axis is on a logarithmic scale.

Table 4.1 – 5 top-selling products of Brasil, except for product 1005 (Corn) that took fourth place in 2019.

SH4 Code	SH4 Description
1201	Soya beans, whether or not broken
2601	Iron ores and concentrates, including roasted iron pyrites
2709	Crude oil from petroleum and bituminous minerals
1701	Cane or beet sugar and chemically pure sucrose, in solid form
0207	Meat and edible offal, of the poultry of heading No 0105, fresh, chilled or frozen
1005	Corn

By observing the $< PRODY >$, we can see how these products with greater sophistication and greater exportation in the the country is reachable or not by other states. In the figure 4.8 we have a better visualization of how products *PRODYs* are distributed among the Bazilian states. For this, the *PRODYs* of all the products were calculated and then the average of the *PRODYs* was calculated. After that, the ones with the best placement were chosen. In this simulation, we measured the average of the best 50 products after 20 interactions, as proposed by Hidalgo et al. (2007). The red color on the chart represents the products in their initial distribution. The other colors - green, yellow, and orange - represent the products after the 20 interactions with proximity, respectively, 0.55, 0.6, and 0.65. As we can see in the figure, all states are able to diffuse in the network up to a point in the $< PRODY >$ value and, consequently, more sophisticated. Despite this, there is a large drop in the number of states that have richer products and can move around the network.

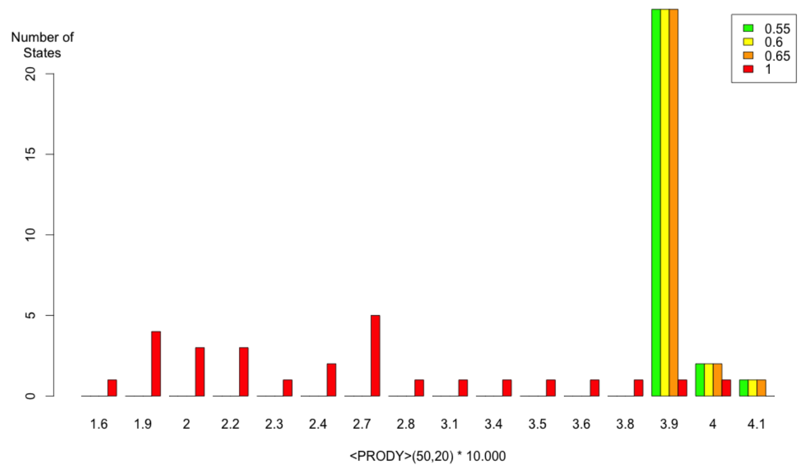


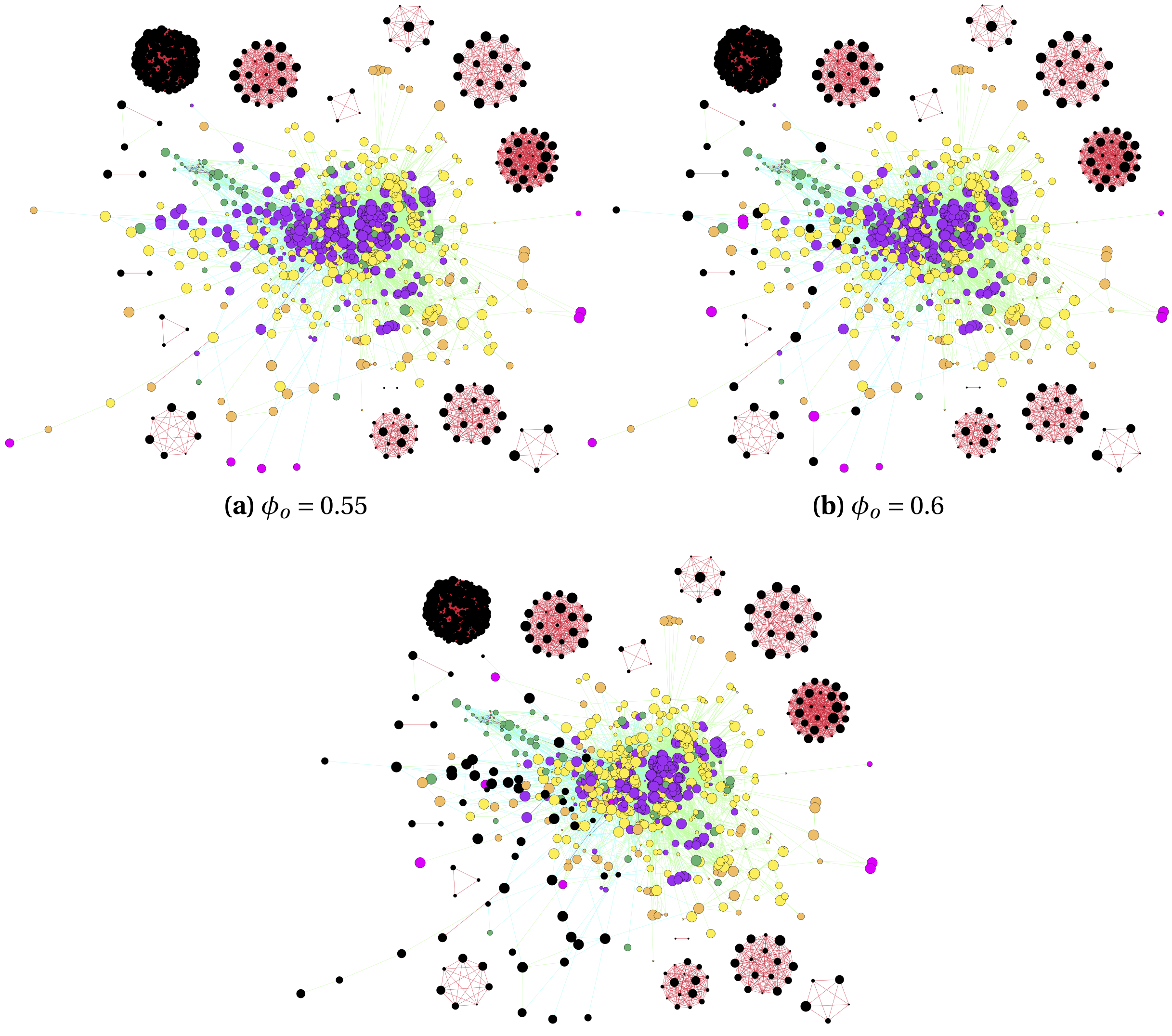
Figure 4.8 – *PRODYs* Average of 50 products after 20 interactions. The color red corresponds to the initial distribution of the products. The colors green, yellow, and orange represent the products after the twentieth interaction achieved with proximity, respectively, 0.55, 0.6 and 0.65.

4.2 RQ2: How could Alagoas advance in the Product Space?

Economies grow by improving the products they produce and export. The technology, capital, institutions, and skills needed to have new products are more easily adapted to one product than others (Hidalgo et al., 2007). Based on product assignments, such as technology and capital, we can build the *Product Space* network. By studying this network, it is possible to visualize which products are most susceptible to becoming new products for the production and export of a particular region. With this in mind, with the Alagoas Product Space network, it is possible to analyze the products already produced and exported by the state and, from them, to "predict" which products are most likely to be produced, increasing the range of opportunities for existing industries/companies in the state or for new industries interested in expanding their markets. From this, we start with RQ2.

A well-connected network can define how far in the network a region can reach and reach more sophisticated products. According to Hidalgo et al. (2007), if a country diffuses to nearby products and they are sufficiently connected to other products, after several interactions, it will be able to reach the noblest area of the network. On the other hand, if the network is disconnected, regardless of the number of interactions to be made, the country will not be able to reach more sophisticated products. Based on this and to better understand how the network diffuses, a simulation has been applied. This simulation shows the position of the region as it moves to products larger than a certain ϕ_o. In this study, 20 interactions were made and the selected ϕ_o for the simulation was $\phi_o = 0.55, \phi_o = 0.6, \phi_o = 0.65$ and $\phi_o = 1$.

We can visualize the diffusion process in figure 4.9. The colors dark green, light green, yellow, light orange, dark orange, and black refer to the number of rounds of the simulation. The first color refers to the products that are already produced in the State of Alagoas with *RCA* >1; the second corresponds to those that are reached with the first round of the simulation; the third with the second round; the fourth with third and fifth with the fourth round of interactions. The black dots indicate products that are not reached by the state or the above four interactions.



(a) $\phi_o = 0.55$ **(b)** $\phi_o = 0.6$ **(c)** $\phi_o = 0.65$

Figure 4.9 – Diffusion Progression. The colors green, purple, yellow, light orange, pink and black refer to the number of rounds of the simulation. The first color refers to products that are already produced in Alagoas with RCA greater than 1; the second corresponds to those that are reached with the first round of the simulation; the third with the second round; the fourth with third and fifth with the fourth round of interactions. The black color indicates products that are not reached by the state or the above four interactions.

Throughout the interactions in the three selected proximities, we can see that Alagoas can reach several products in the first and second interactions. However, the number of black dots - those that are not achieved by the state - grows gradually as we increase the proximity value. This aspect reveals that the state would have more significant difficulties in moving in the network from products that have a little more sophistication. This situation can create problems in the future if migration is required to produce a new product.

We can see that comparing the three graphs, the changes are very plain or almost non-existent when we make a visual analysis. With the figure 4.10 we see clearly how many products are reached in the diffusion simulation. We notice that there is a considerable difference when we analyze how many products are reached from the first to the second interaction. When we visualize the interval from the second to the fourth interaction, a substantial drop in the number of new products is noticeable. Still, when comparing the proximities and the differences between them in the course of the interactions, we realize that from one proximity to another there is not a significant margin of new products reached. Thus, it is noteworthy from the figure 4.10 that, in the first attempt to expand the market, there would not be too difficult in handling taking into account the moderated quantity of products achieved with the first interaction.

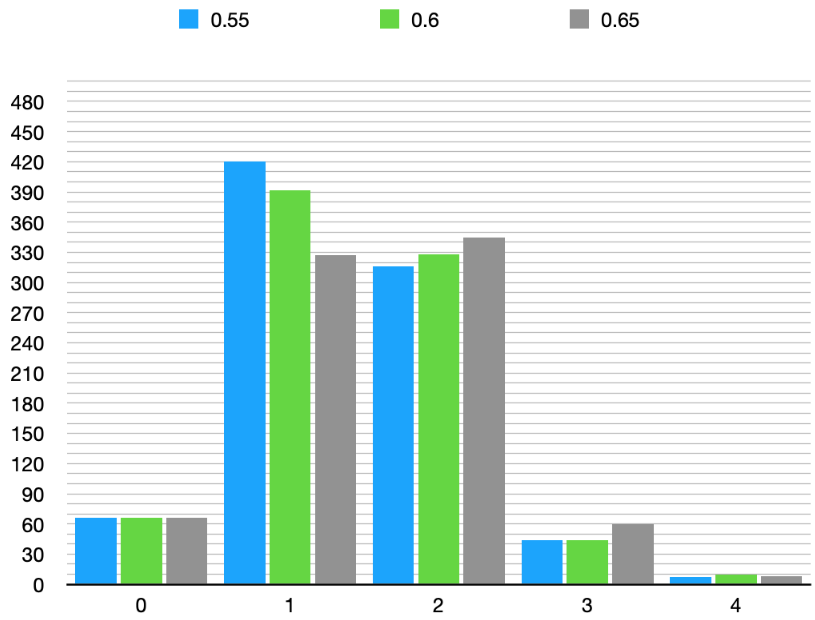


Figure 4.10 – The number of products per number of interactions. The interaction zero are the products already produced by Alagoas. The products proximities are represented by the colors blue, green, and grey.

As pointed out by Hidalgo et al. (2007), *RCA* indicates whether the site is competitive on a larger scale in the trade with a particular product. In 2010, Alagoas had fourteen products with *RCA*>1 and sixteen in 2015. Its most significant drop was in 2011, accounting for 9. In the following years, the state obtained a more significant recovery with the gradual increase of products. In 2019, the number of products with *RCA*>1 reached 66. Concerning all exported products, in 2010, Alagoas exported 136 products. During all the years studied, between 2010 and 2017, the state maintained the same number of products exported.

In Figure 4.11 we have a comparison of the number of products exported with *RCA*>1 from the states of Alagoas, Pernambuco, and São Paulo. The first thing we realize is that the number of products is quite stable in any of the three states in the years presented. The second aspect comprises the low amount of Alagoas products when compared to the other two states. About its neighboring state, Alagoas presents practically ten times fewer products, which can be considered high, despite the considerable increase in 2019. São Paulo has 68 times more products exported with *RCA*>1.

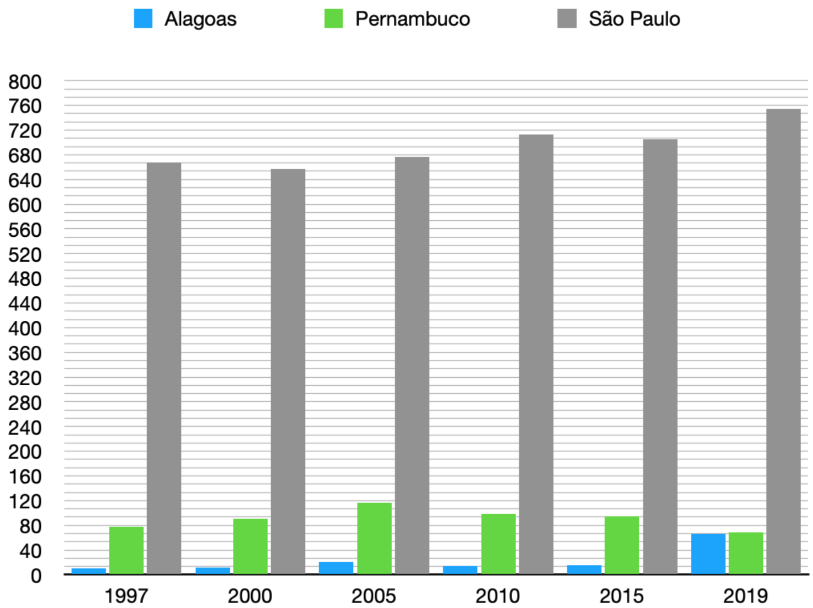


Figure 4.11 – Number of products with *RCA*>1 from the states of Alagoas, Pernambuco and São Paulo in the years 1997 and 2017.

The Alagoas network underwent some changes between the years 1997 and 2019. Some products, with *RCA*>1, have entered their products basket, as well as some are no longer produced. From 1997 to 2000, only one new product was introduced into the network. The most significant entry of new products in the network occurred in 2005, adding eight products in its basket compared to the previous year. In 2019, compared to 2015, fifty products contributed to the growth of the network. This considerable increase in products caused Alagoas to approach its neighbor, Pernambuco, for the first time during the period studied.

Through the diffusion, we can observe the possible migrations of production that can be performed by Alagoas. It would be a way of predicting which products would or would not be more likely to be produced in the future. The products that are achieved through the first diffusion interaction can be easily produced, especially when they have high proximity. Taking into account the greater proximity studied and analyzed in the diffusion process of 0.65, Alagoas has excellent possibilities of migration and expansion of its production. The state reaches, with its first interaction, 261 new products. Only the first five best-selling products, described in Table 4.2, totaled approximately 15 billion dollars in 2019.

Table 4.2 – 5 top-selling products of the first interaction of Alagoas with $\phi = 0.65$

SH4 Code	SH4 Description
4703	Chemical wood pulp, soft drinks or sulphates, except dissolving masses
8703	Passenger cars and other motor vehicles primarily designed for the transport of persons (except those of heading 8702), including mixed-use vehicles (station wagons) and racing cars
8708	Motor vehicle parts and accessories of headings 8701 to 8705
8704	Motor vehicles for the transport of goods
0203	Meat of porcine animals, fresh, chilled or frozen

When analyzing one of the best selling and last products exported, in 2019, by Alagoas (considered the number of dollars), respectively, with code *SH4* 1701 (Sugars from sugar cane or beet and chemically sucrose pure, solid-state) and 3916 (Monofilament of which any cross-sectional dimension exceeds 1 mm, rods, sticks and profile shapes, whether or not surface worked but not otherwise worked, of plastics), we have noticed that even with a difference in export value, the former with 444 million of dollars and the second with a little more than 260 thousands of dollars, they have a very distinct number of neighbors in the network.

We can see in the figures 4.12 and 4.13 their evolution during the years of 1997, 2000, 2005, 2010, 2015, 2017 and 2019. The first aspect that we observed in the data studied is that the sugarcane product does not appear in 2017. This year, the product has no proximity above 0.55, as determined in Hidalgo et al. (2007). Due to this factor, it does not appear in the network in 2017. We also noticed that during the other years, the product 1701 has no proximity to a large number of products. In addition, there is no red link, which determines high proximity and a high chance of producing a new product.

Regarding product 3916, we realize that in all years it has a greater amount of links among other products than product Cane. Despite being one of the last products sold in the export basket of Alagoas, the state would have more chances to reach a new product from it. Most of its links are light blue and green, unlike the product 2846, one of the last products sold by São Paulo (in figura 4.14), which mostly are in red.

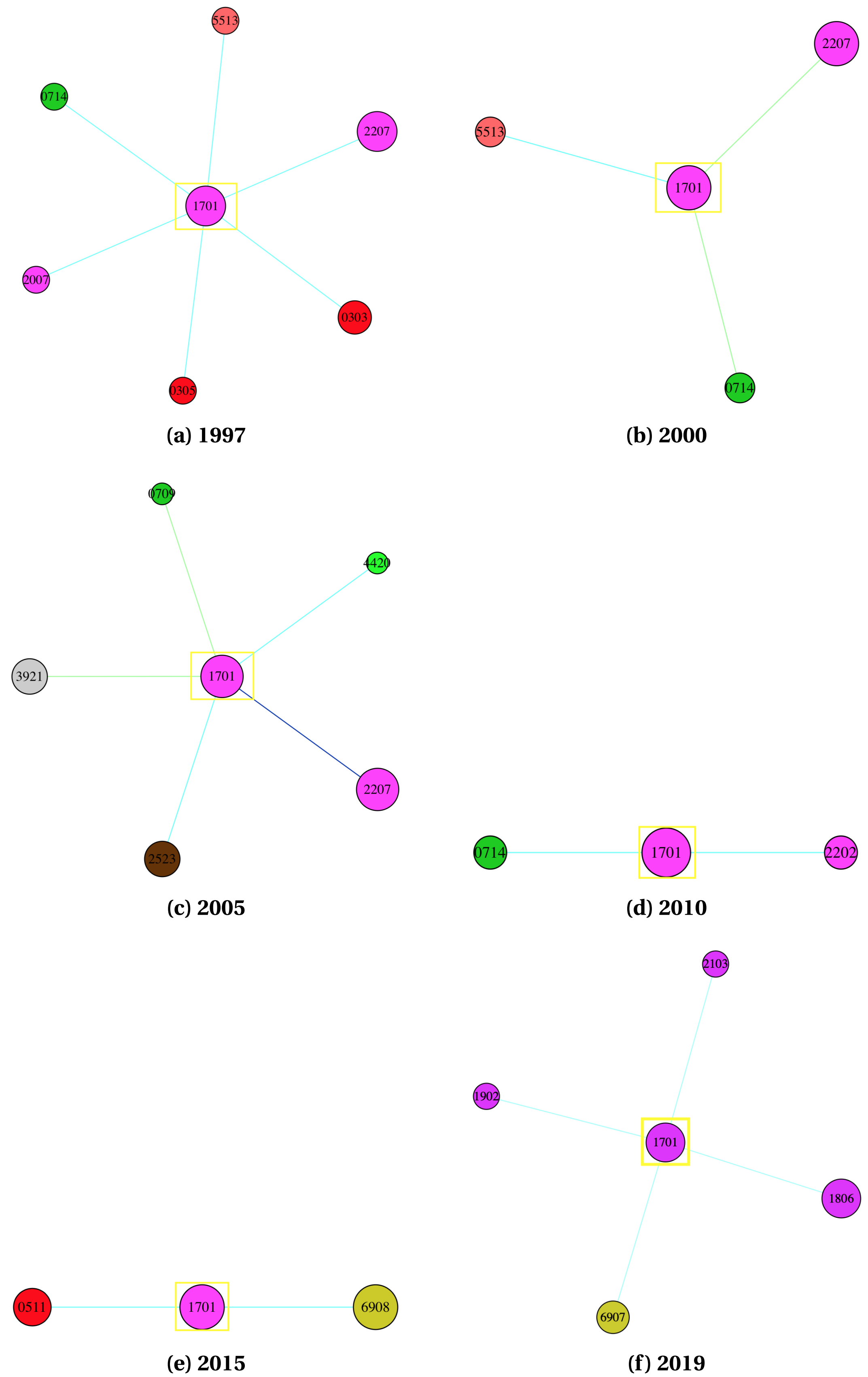
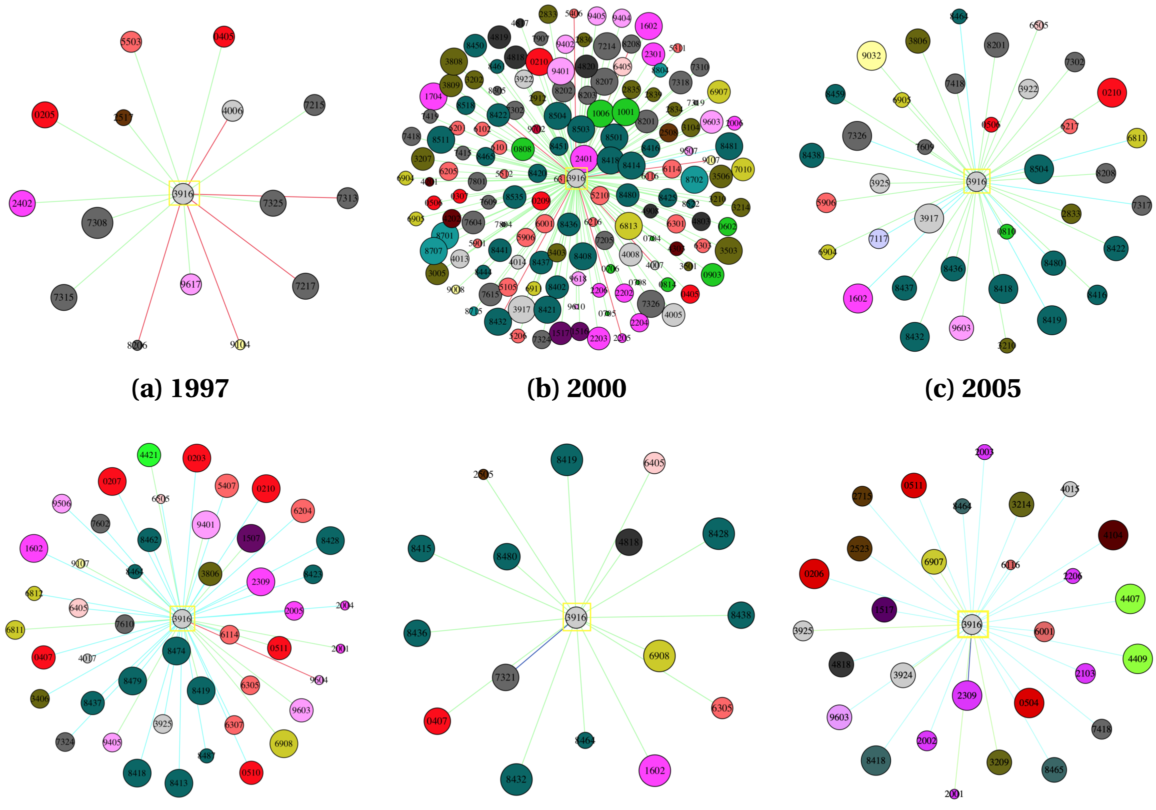


Figure 4.12 – In yellow boxes is represented the product 1701 (Cane or beet sugar and chemically pure sucrose, in solid form) referring to the first in the export network of Alagoas and São Paulo - considering the dollar value of exports of the state.



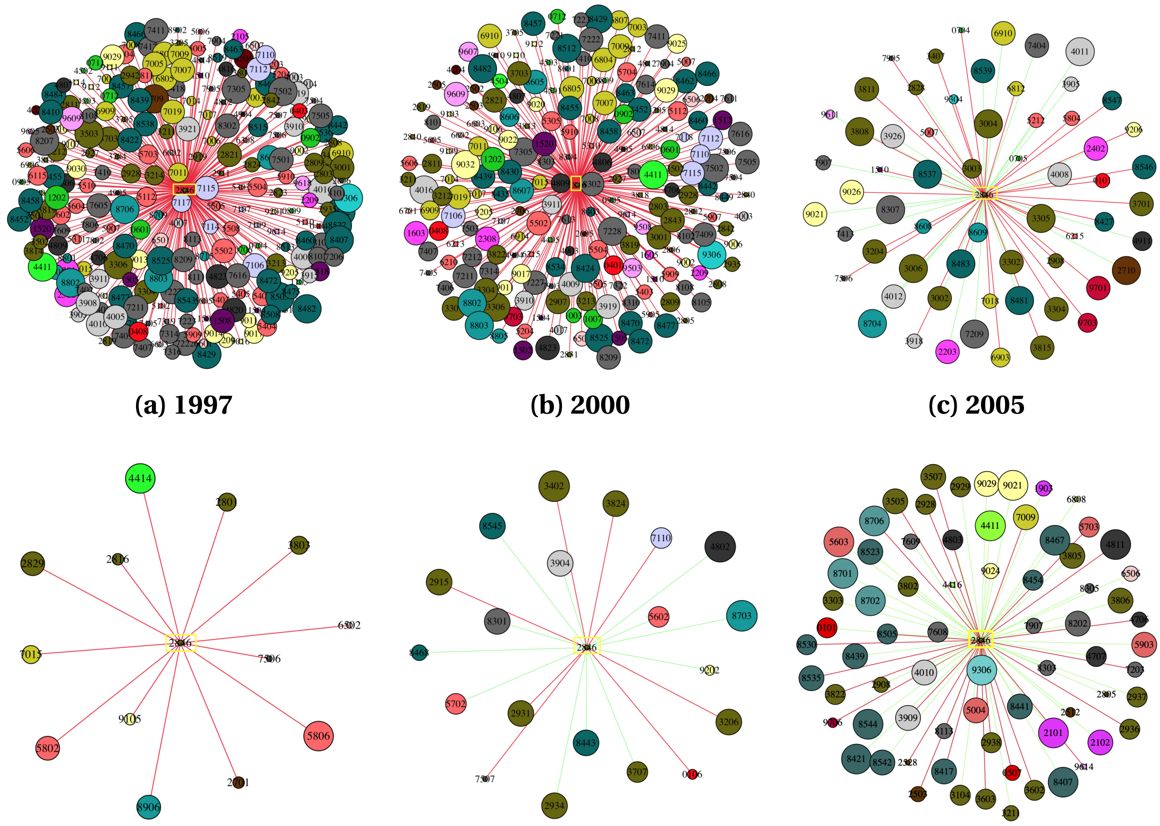
(a) 1997 (b) 2000 (c) 2005

(d) 2010 (e) 2015 (f) 2019

Figure 4.13 – In yellow boxes is represented the product 3916 (Monofilament of which any cross-sectional dimension exceeds 1 mm, rods, sticks and profile shapes, whether or not surface worked but not otherwise worked, of plastics) referring to one of the last in the network of export of Alagoas - considering the value in dollars of exports of the state.

In both examples of the figure 4.12 and the 4.13, we realize that products from other categories can be produced from a different category. In the example of the figure 4.12, we start from the grocery category, to which the cane belongs, and find very different categories such as articles of stone and other materials. In the figure 4.13, with a wider range of products that can be reached by diffusion, the category transition would be from plastic and rubber to grocery, animal products, machinery, instruments, among others. Such examples can demonstrate that, even if a location has products in only one type of category and although it seems impossible to produce different products, it would be possible to migrate to another product of different categories, given a certain time and investment for such action.

Alagoas and São Paulo have the same product at the top of the export list. The difference between the states is the cash amount acquired with the export of Cane in 2019. Alagoas exports a little over 195 billion dollars, while São Paulo exports more than 3 trillion. Compared with the year 2015, we noticed a small drop in the value of exports in Alagoas. And in São Paulo, there was also a drop of approximately 10% in its export. While Alagoas exported a little over 469 million dollars, São Paulo exported more than 4 trillion. Despite presenting a large amount, in dollars, on sale concerning the great majority of other exported products, both states have suffered a drop in the sale of this product over the years studied.



(a) 1997 (b) 2000 (c) 2005

(d) 2010 (e) 2015 (f) 2019

Figure 4.14 – In yellow boxes is represented the product 2846 (Compounds, inorganic or organic, of rare-earth metals, of yttrium or scandium or mixtures of these metals) referring to one of the last ones in the network of export of São Paulo - considering the dollar value of export of the state.

In the figure 4.14 we have the product 2846 (Compounds, inorganic or organic, of rare-earth metals, of yttrium or scandium or mixtures of these metals), one of the last in the export list of São Paulo. As we can see, there is a variation in the number of products to which the 2846 product has proximity. In 1997, its cluster was quite dense, with high proximity between products. We can notice a small drop in 2000, and in the following years (2005, 2010 and 2015) we noticed a very high drop in the number of links. Despite this, there was a considerable increase in products in 2019. Continuously checking product networks can be a good strategy for evaluating previous years and whether that product is opening the door for possible new product deployment in your industry. In the case of product 2846, with the study of previous years, we can see with its variation the entry and exit of Brazil from the crisis that took place in 2015.

4.3 Threats and Implications

The data collection may be one of the threats to this work, so that this data may not reflect the real scenario of Alagoas and Brazil export. To mitigate such a threat, all data was acquired from the official Brazilian government database. Some procedures are taken to validate and avoid errors in the collection of this data. Regarding this matter, all references of the exported products are made on the date of departure of the product from the national territory, according to the recommendation of the UN (United Nations). Concerning the export analysis, according to (Ministério da Indústria, 2018), the DEAEX (Departamento de Estatística e Apoio à Exportação) aims to check any errors in completing the records, in the questions that refer to the statistical values (value at the place of shipment, net kilogram and quantity in the statistical unit of the product code), guiding the export operators about their correction. The refresh rate for this database is given every month for those who want to gather new information.

The database used by Hidalgo et al. (2007) was not used in this work due to its data is not granular enough for the investigations to be conducted. This database refers to the international trade data, not accounting data referring to the Brazilian states.

Another threat to this work is the reliability of the technique used. Such a threat may invalidate conclusions if the result provided by the Product Space technique does not reflect actual export behavior. To mitigate this threat, we analyzed the results reported by other authors to verify how these data can be evaluated in practice. It is concluded that the results reported by them exhibit interesting results and reflect reality. For example, according to Felipe et al. (2010), China not only started producing one different product but shifted from agricultural activities (especially on farming) into reliance on modern industrial and service sectors. This process took place from 1980 until 2007.

Such results and reliability in the technique used contributed to this project. First for those who yearn to invest in the Brazilian market, both as governors or investors. And second, for those who wish to analyze with academic purpose.

With the study of the Product Space network, we realized that Alagoas has the possibility of growth from the products that are already exported by the state. A process like diffusion that can demonstrate products that is possible to become produced in some years could guide the government, or even some outsider investors, to take a different look at a specific niche. With such information, more effective investments could take place, generating income and jobs. Besides, governments can create policies that encourage investment in growing or expanding areas, facilitating the entry of new industries.

There is also a contribution to researchers. With this study, a lack of possible analyzes of the Brazilian export network was opened, providing a public dataset where researchers can access and conduct more analyzes. For example, other researchers can choose a specific niche or Brazilian state and learn how they have behaved in previous years and which products are more easily produced through diffusion. With these data, it is possible to make specific recommendations on investments to leverage the production of the chosen area.

Through data studies, we can see that Alagoas has few products with relevance to the international market. Over the 20 years studied we have also seen that the quantity of these products remains practically the same. Such a scenario may demonstrate that there is not much interest in expanding the market for other products with a vaster market impact. In addition, it can demonstrate that there is a lack of incentives for the movement of new goods and new industries. Despite this, Alagoas is not totally isolated in the Product Space network. Regardless of reaching a few new products in the first interaction of the diffusion, the state has the possibility to grow and reach even more products in the second stage of diffusion.

We also see that there are more connections in products that are not in the first place, in dollars, in exports. As we can see from the 4.13 and 4.14 figures, they have a much higher number of links to other products when compared to sugar cane. Such a difference in the number of new products that can be achieved and produced in the future can open a door for investors to look at these products differently. Perhaps it would be better to invest in products that are now among the least exported products so that in the future there will be a wider range of products to which the state could reach. To continue investing only in products such as sugar cane, which does not have half the possibility of diffusion of the product 4.13, may impact the state growth since there will not be many options for the production of new products. This kind of information can be taken as an incentive to search for products that are not so sought after by large industries and give a boost to new investments.

5 Conclusion

In this paper, we seek to show how the Brazilian market, and specifically Alagoas, behaved during the years 1997 and 2019 regarding the quantity and sophistication of products produced. Also, we can ascertain whether the state of Alagoas has the possibility of growth through products and technologies already developed by the state.

Brazil is a country with a sizeable territorial dimension and has a great diversity in products mostly characterized as raw material. Despite this, almost all wealth and economic activity are concentrated in a minimum number of states and a small portion is related to products that have a higher sophistication.

The products basket of the states remains practically the same among the years studied. Through the 4.11 chart, we see that the changes are minimal. There is almost no evolution in any of the states, whether rich or poor. Such a trade structure may hinder the transition to new products by less favored states, as no investment or new policies is being made in favor of their growth.

Despite the minimal changes over the years, we can conclude from the results that Alagoas is not wholly isolated from the marketplace. There is room in the market for the growth of the state network. Containing only 16 products with $RCA > 1$, Alagoas manages to reach, which we can see through diffusion, a limited number of new products that also have an impact factor in the Brazilian market. Even though, the state could produce new products based on technologies already used in other exported products, which could facilitate the company's transition to its production.

The absence of the transition to other products may occur due to the lack of structure needed to accommodate new products that also have a shocking effect on the domestic market. Greater financial and intellectual investment, machinery and more recent technologies, etc., would be necessary for this transition. Also, it would be necessary to increase policy applications that facilitate the entry and retention of products on the market. Besides, it would demand policies that encourage the growth of the products already produced by the region to try to increase the demand of the quantity exported.

The results of this work are being written in article form for journal submission. Future research can be performed using our database for further study of both the state of Alagoas and the other states present in Brazil. Besides, there is the possibility of reshaping data and conducting research for countries and states around the world.

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