Structural analysis of the economy of Puerto Rico after the elimination of Section 936: A network-based approach*

Análisis estructural de la economía de Puerto Rico tras la eliminación de la Sección 936: Un enfoque basado en redes

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ABSTRACT

This paper studies the productive structure of Puerto Rico after the elimination of Section 936 of the US Internal Revenue Code. To examine the productive structure, input-output (I-O) and network analysis techniques were used, as well as the 2007 and 2012 I-O matrices for Puerto Rico. It was possible to illustrate the significant relations in the structure. Through Density, it was found that transactions experienced a minimal increase. In addition, it was found that manufacturing had a significant Outdegree measure but minimal Indegree and PageRank measures. Besides, it was found that the new construction, municipal government, arts, and sports spectator's sectors had high PageRank measures. It is recommended that an import substitution policy be established in the industries that make up the manufacturing sector. Diversifying the core components of the productive structure is also recommended.

RESUMEN

Este trabajo estudia la estructura productiva de Puerto Rico luego de la eliminación de la Sección 936 del Código de Rentas Internas de Estados Unidos. Para examinar la estructura productiva se utilizaron técnicas de insumo-producto (I-P) y análisis de redes, así como las matrices I-P de 2007 y 2012 para Puerto Rico. Fue posible ilustrar las relaciones significativas en la estructura. A través de la Densidad, se encontró que las transacciones experimentaron un incremento mínimo. Además, se encontró que el sector manufacturero tenía una medida de *Outdegree* significativa, pero tenía medidas de *Indegree* y de *PageRank* mínimas. En adición, se encontró que los sectores de nueva construcción, gobierno municipal, artes y espectadores deportivos tenían medidas de *PageRank* altas. Se recomienda establecer una política de sustitución de importaciones en las industrias que conforman el sector manufacturero. También se recomienda diversificar los componentes del núcleo de la estructura productiva.

INTRODUCCIÓN

The world's economies, including the economy of Puerto Rico, are a collective of different sectors that produce goods and services. Furthermore, these sectors can be differentiated due to their output and the goods and services they must acquire to complete their production process. For example, it is expected that the manufacturing sector will need to acquire significant amounts of energy to

complete its production process, whether it is medicines, chemicals, or textile products. Therefore, the sectors of an economy are connected through their Input-Output relationships, which can be visualized through networks.

Through these visualizations, it is possible to know the changes and evolution of a productive structure through the business cycle and over time, which can have important implications for conducting fiscal and regulatory policy (Foerster and Choi, 2017). For example, suppose the government establishes a new regulatory framework or a tax reform that seeks to increase or lower corporate taxes to a giving sector. In that case, the sector subject to the new legislation may change its way of conducting business. Therefore, the magnitude of the spillover effects may depend on the number of links of that sector with the rest of the economy.

For Puerto Rico's case, it has been pointed out in the literature that after the elimination of Section 936 of the United States of America (US) Internal Revenue Code, an industrial policy must be established that leads to economic growth due to the possibility that the economy is on a federal grants bubble and the vulnerability of this economy to a new situation of insolvency in its public finances (FOMB, 2023; Romero-Ramírez, 2024). In other words, Puerto Rico's economy needs to grow sustainably in the long term. Therefore, it is essential to identify the sectors of the Puerto Rican economy with higher links with the rest of the economy as a first step to establishing new economic policies (industrial, fiscal, and regulatory) to encourage or withdraw incentives from a sector or a group of sectors.

The need for new industrial, fiscal, and regulatory policy designs makes Puerto Rico an excellent case to know: What are the main characteristics of the productive structure of Puerto Rico after the elimination of Section 936? This paper aims to determine the main characteristics of the productive structure of Puerto Rico after the elimination of Section 936. In addition, it aims to analyze and evaluate the inter-industrial relations of Puerto Rico's internal economy. Due to the availability of the data and the year to which that data corresponds, it is expected that after the elimination of Section 936, the productive structure should be a denser and more complex network of relationships; this will be explained in further sections of this paper.

Knowing the main characteristics of the productive structure of Puerto Rico would serve to formulate new economic policies in a moment of high risk and uncertainty. Techniques of the Input-Output model and Network Analysis will be used to answer the research question. Therefore, even though this will not be the first study that uses these methods for the case of Puerto Rico (Luciano, 2005; Ramos, 2023; Romero-Ramírez, 2024), it will be the first to introduce the PageRank measure. However, this paper will primarily be an extension of the analysis performed by Romero-Ramírez (2024). Also, this paper will be the first to study the 2012 Input-Output matrix of Puerto Rico since previous research has only used the matrix from 2007 to study the productive structure in the post-2006 era (Ríos, 2019; Ramos, 2023). Besides, one of the main problems with the Input-Output matrices of Puerto Rico is that the series does not have the exact dimensions, which can complicate any analysis that wants to evaluate changes over time and the business cycle; by aggregating the matrices of 2007 and 2012 to 30 sectors this paper contribute to generating a uniformed series of matrices.

This paper is organized as follows: the first and second sections present a literature review on the economy of Puerto Rico after the elimination of Section 936 and the methodological literature review; the third and fourth sections present the methodology used in this paper and the results; the final section discusses the conclusions and policy recommendations.

I.   PUERTO RICO AFTER THE ELIMINATION OF SECTION 936

During the postwar period, Puerto Rico's economy experienced significant transformations that led it from being a primarily agricultural economy to a model of industrialization by invitation. This model can be divided into

several stages: the first focuses on clothing, the second on heavy industries such as refining and petrochemicals, and finally, pharmaceuticals and electronics (Quiñones-Pérez and Seda-Irizarry, 2016). The last stage was linked to Section 936, which allowed US corporations to receive full credit from income for maintaining operations in US territories, Puerto Rico being one of those territories (Feliciano, 2018).

Figure 1.
**Gross National Product of Puerto Rico at constant 1954 prices**
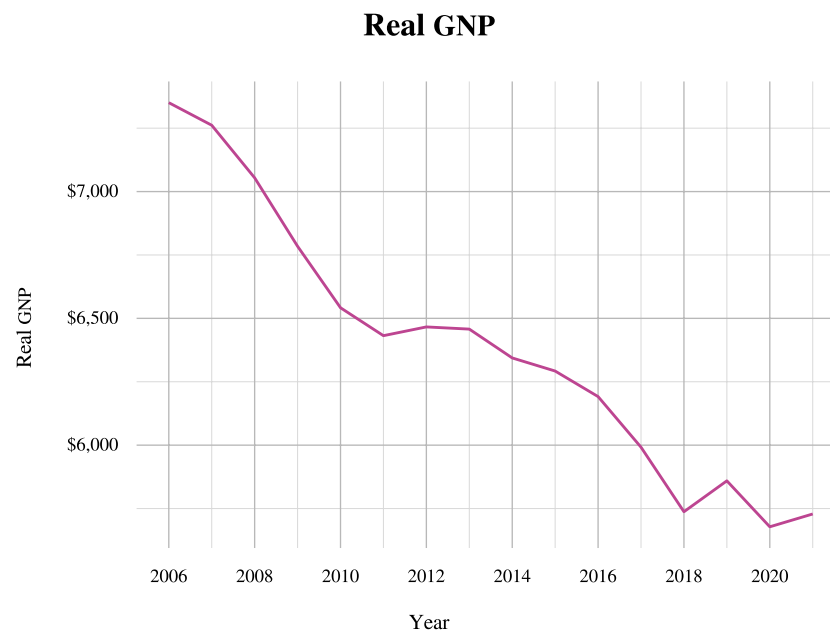
Real GNP

This tax regime played a crucial role in Puerto Rico's economic performance for over 30 years since Caraballo-Cueto and Lara (2018) argue that during the moment of most success of Section 936, manufacturing represented 30% of deposits on local financial institutions, it represented 17% of total employment and represented 42% of Puerto Rico's Gross Domestic Product (GDP). However, this tax regime was eliminated in 1996, and a 10-year phase-out period was established to allow an organized transition. Nevertheless, a substitute model was not established, and the island production capacity decreased significantly (Ríos, 2021), as evident in Figure 1.

From Figures 1 and A1 of the appendix of this paper, it is possible to indicate that the production capacity of Puerto Rico's economy collapsed after 2006. Since then, the production capacity has only shown the ability to grow again in 2012, 2019, and 2021. In the case of 2012, according to Quiñones-Pérez and Seda-Irizarry (2020), because of the Global Financial Crisis of 2007-2008, Puerto Rico's economy received a fiscal stimulus of over $30 billion, which translated into a growth of 0.5% for the fiscal year 2012. Regarding the growth experience after 2017, some economists argue that due to Hurricane María, which devastated Puerto Rico in September 2017, the earthquakes of January 2020, and the COVID-19 pandemic, the economy of Puerto Rico will receive approximately $122 billion as a fiscal stimulus from the US Federal Government (Fuentes, 2022), which can have had an impact on economic growth.

Figure 2.
Federal Grants of Puerto Rico at constant 1954 prices

Federal Grants
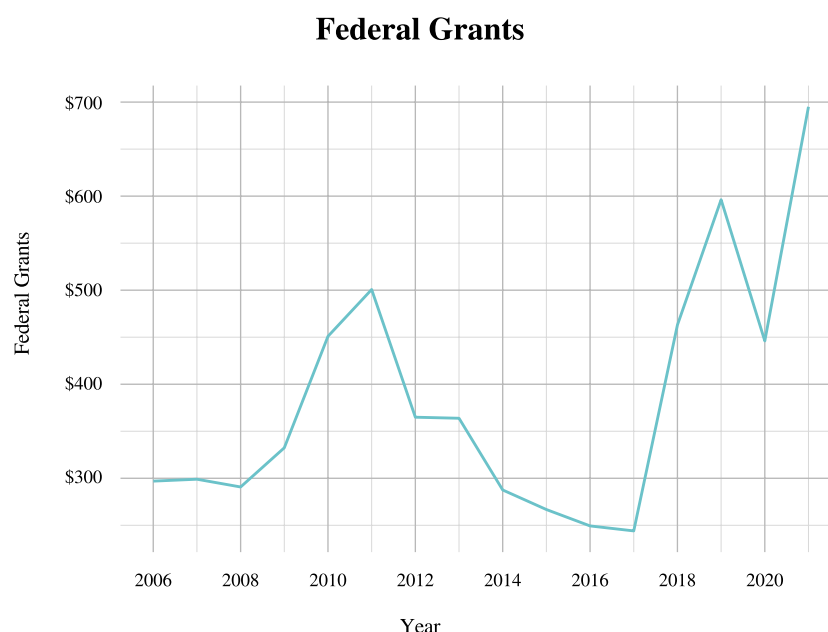
Source: author's own elaboration using data from the Puerto Rico Planning Board (2023a).

In Figures 2 and A2 of the appendix of this paper, it is possible to see that for the periods after the Global Financial Crisis and Hurricane María, the economy of Puerto Rico received massive injections of grants, and the level of these injections only occurred on extraordinary circumstances, because they are not recurrent grants/transfers. This reality has led many economists to argue that Puerto Rico is currently under a federal grants bubble that has led to ephemeral economic growth (Caraballo-Cueto, 2021), which led the Financial Oversight & Management Board for Puerto Rico (FOMB) to make a simulation where they extracted the effects of the federal grants on the Real Gross National Product of Puerto Rico (GNP) (FOMB, 2023). The simulation can be observed in Figure 3, from which it is inferred that without federal grants, the growth of Puerto Rico's economy would be on negative values in all years except one of them, 2021.

Figure 3.
Puerto Rico's Real GNP Growth without Federal Grants

Real GNP Growth w/o Federal Grants (%)
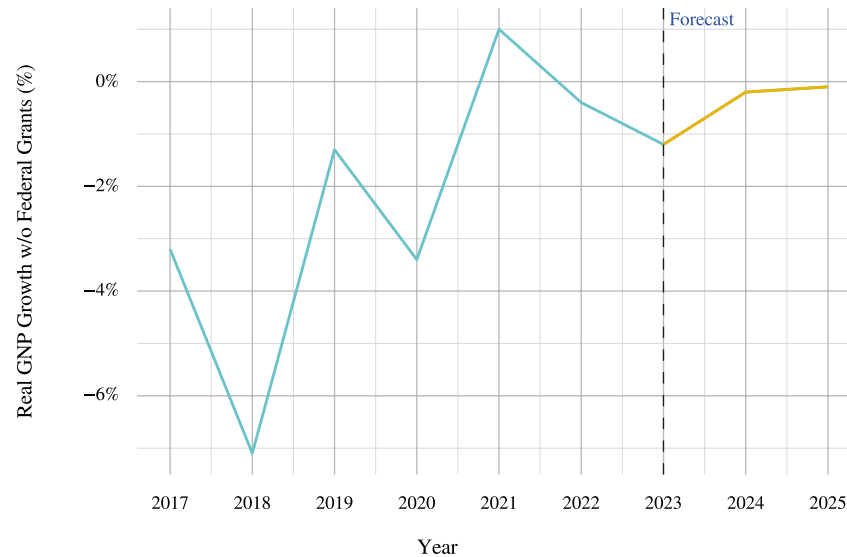
Source: author's own elaboration using data from the FOMB.

The simulation confirms the positions of several economists that the economy is in a federal grants bubble and can grow when receiving massive fiscal stimulus from external sources. This situation places Puerto Rico in a very dangerous situation since, in recent years, several of Puerto Rico's debts have been restructured, such as the bonds from the Puerto Rico Urgent Interest Fund and the bonds of General Obligation (Quiñones-Pérez and Seda-Irizarry, 2020; Romero-Ramírez, 2024), for which the viability on the long-term of these debt adjustment plans is uncertain.

While growth has become dependent on federal grants, and public authorities have been immersed in the restructuring process of the public debt, in terms of industrial policy, or rather in the absence of it, the Government of Puerto Rico, through recent years, has established specific strategies to attract investment. For example, Acts 20 and 22 of 2012 (currently part of Act 60 of 2019) aim to attract investment to Puerto Rico. There is only one study on both acts' economic effects. This study applied a Bayesian structural time series model to create a counterfactual series where these acts did not exist and compared it with the conventional synthetic control method. The study concluded that at the end of the period, total output and total employment were 2% and 3% higher (respectively) than their counterfactual levels (Econometrika Corp., 2021). Besides, public perception regarding individual investors is not favorable since some studies have highlighted the negative experience of native Puerto Ricans who had crossed paths with individual investors from Act 22; these citizens argued that the individual investors have hoarded properties and evicted households (Santiago-Bartolomei *et al.*, 2022). Also, in 2022, the Department of Economic Development and Commerce of Puerto Rico, the local agency in charge of formulating trade and industrial policies, published a strategic framework for economic development named *PRopósito* (DDEC, 2022). Nevertheless, it is essential to note that this framework for economic development lacks clear objectives and goals, objectives that are measurable and contrastable, specific strategies not based on

short-term opportunities, procedures that will be followed to achieve the objectives, strategies, and initiatives, and execution plans; in other words, Puerto Rico does not have a clear and defined industrial policy.

In summary, after the elimination of Section 936, Puerto Rico's production capacity collapsed. However, the economy has been able to show signs of improvement only when the island receives massive fiscal stimulus. Therefore, the economy seems to be in the middle of a federal grants bubble until those grants reach average levels. When those grants return to their average level, Puerto Rico may return to negative Real GNP growth rates, higher migration, and possibly a second default on debt service. Consequently, it is essential to identify the main characteristics of Puerto Rico's inter-industrial network; with these characteristics, it will be possible to identify the sectors with higher links, and the government will be in a position to make informed policy changes regarding industrial, fiscal, and regulatory issues that lead to economic growth in the long run.

II.   METHODOLOGICAL LITERATURE REVIEW

In economics, many methodological approaches aim to study economic phenomena and perspectives. For example, in macroeconomics, methodological approaches from the perspective of time series econometrics usually dominate, while in microeconomics, approaches from cross-sectional econometrics are widely used. There are also many other statistical/mathematical methods and qualitative approaches, such as focus groups and interviews with human beings. However, economists interested in regional analysis from an international or national perspective usually use methods such as Input-Output Analysis, integrated Input-Output models and econometrics, spatial econometrics, and gravitational models. All the methods above have different characteristics and are applied depending on the research question the researcher is trying to answer. This section will review literature linked to Input-Output Analysis and Network Analysis.

The Input-Output Analysis, at least as we know it today, has its origin in the study of Leontief (1936); this study had the purpose of presenting for the first-time concepts similar to the Tableau Economique for the case of the US economy in 1919. Over the years, Input-Output matrices have traditionally been constructed with data from a particular country or region. This model can be defined in the following way: It presents the activities of different industries/sectors that produce goods and services and are consumers of goods and services produced by other industries/sectors during their production process (Miller and Blair, 2009); the authors add that through this model, it is possible to study the impact of an industry on an economy and determine the significant industries of a productive structure. Okamoto (2021) argues that those applications are possible because the model provides a picture of the entire economy regarding supply and demand relationships in the system. Therefore, these models have a general equilibrium framework (Ortíz and Castro, 2008). All these characteristics led us to choose the Input-Output Analysis as the methodological approach to answer this paper's research question.

The main branch of the Input-Output Analysis is the quantitative approach, where multiples indices seek to identify significant sectors, the level of integration, or even the effects on total and sectoral production if a sector no longer exists (Motohashi, 1998; Dietzenbacher and Lahr, 2013; Romero-Ramírez, 2023a). Nevertheless, Aroche (2003) argues that quantitative Input-Output Analysis fails to explain aspects of a given structure; as a result, the nature of the connections is not entirely understood. Aroche (2003) adds that qualitative Input-Output Analysis provides different information that quantitative approaches cannot present. Consequently, this paper will follow a qualitative approach, as Aroche (2003) explained.

However, qualitative Input-Output Analysis is related to other methodological approaches that can be complementary; one of the approaches is Network Analysis. This field has been applied by natural scientists and social scientists in different studies (Aroche, 2003; De Benedictis *et al.*, 2014). Within economics, it has been used in different studies about international trade and industrial policy that used Input-Output data (Amador and Cabral, 2017; Pacheco, 2018; Vélez, 2020; Romero, 2022; Ramos, 2023; Romero-Ramírez, 2023b, 2024). In these studies, the authors mentioned above have used different network measures to determine and identify the characteristics of productive structures, such as Diameter, Density, Outdegree, Indegree, Betweenness Centrality, and others. With these measures, it is possible to determine if a given network has experienced growth in its connections and the roles of the economic agents in the network.

To summarize, this paper will follow a qualitative Input-Output approach, as Aroche (2003) explained. In this part of the methodology, the technical coefficients matrix and a filter will be used to generate a binary matrix; afterward, the binary matrix will be used to graph the significant relations in Puerto Rico's network. Then, different Network Analysis measures will be used to determine if the network has experienced growth and identify the system's characteristics.

III. DATA AND METHODS

This section will present the data and the empirical method used to study the productive structure and its core components regarding internal transactions. The Input-Output matrices of Puerto Rico for 2007 and 2012 will be used to perform the proposed analysis, which is data that the Puerto Rico Planning Board published. The matrix of 2007 has a dimension of 110 x 110; therefore, it represents transactions between 110 industries. In contrast, the matrix of 2012 has a dimension of 109 x 109; consequently, it represents transactions between 109 industries. Since both matrices had different dimensions and, in some cases, some industries do not appear in the 2012 matrix, and vice versa, it was decided to aggregate both matrices into 30 sectors equivalent to each other. Also, the 30 sectors were assigned codes to facilitate the estimations of the networks (see Figure A3 and Table A1 in the appendix), and the R programming language was used to perform the estimations. Our first step is to use the Technical Coefficients Matrix (A); in this matrix, each element a_{ij} represents the proportion of the merchandise of sector i used as an input in producing a unit of the merchandise of sector j; Matrix A can be defined as:

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \qquad (1)$$

Our next step is to use a filter that translates real numbers into binary ones. A standard filter is proposed by Aroche (1993); in this filter, n is the number of columns/rows in Matrix A. Therefore, n is a representation of the number of sectors in our matrix. The filter of Aroche (1993) can be defined in the following way:

$$f = \frac{1}{n} \qquad (2)$$

In the previous equation, if the value of cell *i* in Matrix *A* exceeds *f*, the corresponding cell *i* in the Binary Matrix (*W*) will count as 1; if it does not exceed *f*, it will count as 0, Matrix *W* can be defined as:

$$W = \begin{pmatrix} w_{11} & w_{12} & \cdots \\ \vdots & \ddots & \\ w_{m1} & & w_{mm} \end{pmatrix} \tag{3}$$

In the Binary Matrix (*W*), the element w_{ij} represents the edge between vertices *i* and *j*. Also, it is essential to note that the rows of Matrix *W* serve as a list of the outgoing edges from the vertex of that row, and the columns serve as a list of the incoming edges of the vertex of that column. For this matrix, elements w_{ij} will be equal to 1 when there is a significant relationship between sectors *i* and *j*. When those elements are equal to 0, sectors *i* and *j* have no significant relationship. Therefore, the network will be built from Matrix *W*.

The first network measures that will be used are Diameter and Density; Newman (2010) argues that Diameter is a representation of the number of edges that should be traversed to get from one end of the network to the other end of the network under consideration. This measure makes it possible to determine how extensive the network is. Besides, Density is a representation of how tightly connected the network is; this network measure can be defined in the following way:

$$\rho = \frac{m}{\binom{n}{2}} = \frac{2m}{n(n-1)} \tag{4}$$

In the previous equation, m is a representation of the number of edges. Also, ρ can be considered in the $0 \leq \rho \leq 1$ range. If ρ is equal to 1, it is considered that the network is wholly connected with the maximum number of edges. However, if it is equal to 0, the network is considered to have no edges. These measures can be interpreted in the following way: an increase in Density would be considered equivalent to an increase in economic transactions between sectors, and an increase in Diameter would imply that more sectors participate in the network. Besides, it is possible to study the vertices in the network; two measures facilitate the evaluation of the roles of the vertices, and these measures are Indegree and Outdegree. Both measures can be defined in the following way:

$$d\_out_i^t = \sum_{j=1}^{N} \overrightarrow{w_{ij}} \qquad \text{and} \qquad d\_in_i^t = \sum_{i=1}^{N} \overrightarrow{w_{ij}} \tag{5}$$

In equation 5, the Outdegree is a representation of the outgoing edges; a significant Outdegree will be equivalent to a significant seller in the network. While Indegree is a representation of the incoming edges, in this case, a significant Indegree will be equivalent to a significant buyer in the network (Romero-Ramírez, 2024). The following measure used will be PageRank, which originates from Brin and Page (1998). PageRank can be defined as:

$$PR_i^t = \frac{1-\alpha}{N} + \alpha \sum_{j=1}^{N} \frac{PR_j^t}{d\_out_j^t} \tag{6}$$

The PageRank measure is between 0 and 1, and it helps to determine the importance of the sector position in the network (Wang and Yang, 2022). According to Roh (2023), PageRank highlights the significance of neighboring nodes; in other words, this measure can determine the importance of a sector (node) by considering the importance of the other connected sectors. Therefore, a sector under PageRank will be significant if

the sectors connected to it are important buyers or sellers. Our final network measure used in this study is Betweenness Centrality, as defined in equation 7.

$$x_i = \sum_{st} \frac{n_{st}^i}{g_{st}} \tag{7}$$

Where n_{st}^i is the number of geodesic paths between nodes *s* and t that pass through *i*, it is also considered that g_{st} represents the total number of geodesic trajectories between *s* and *i*. It is important to note that this measure pretends to determine the extent to which a node in the network is on the routes of other nodes (Vélez, 2020). Besides, this measure makes it possible to detect communities or sub-networks within the network.

IV.   RESULTS

As mentioned above, identifying the main characteristics of an Input-Output network is a fundamental first step to carrying out policy intervention. This section presents several network measures that facilitate the evaluation of these characteristics. The first estimated measurements were Diameter and Density; these results can be seen in Table 1. The Diameter results suggest that the same number of sectors participated in the network for both years. In contrast, the Density results suggest a minimal increase in transactions between the sectors participating in the network. These results are consistent with the economic growth generated from fiscal stimulus after the Global Financial Crisis of 2007 and 2008, where Puerto Rico experienced a growth of 0.5% in 2012 (Quiñones-Pérez and Seda-Irizarry, 2020).
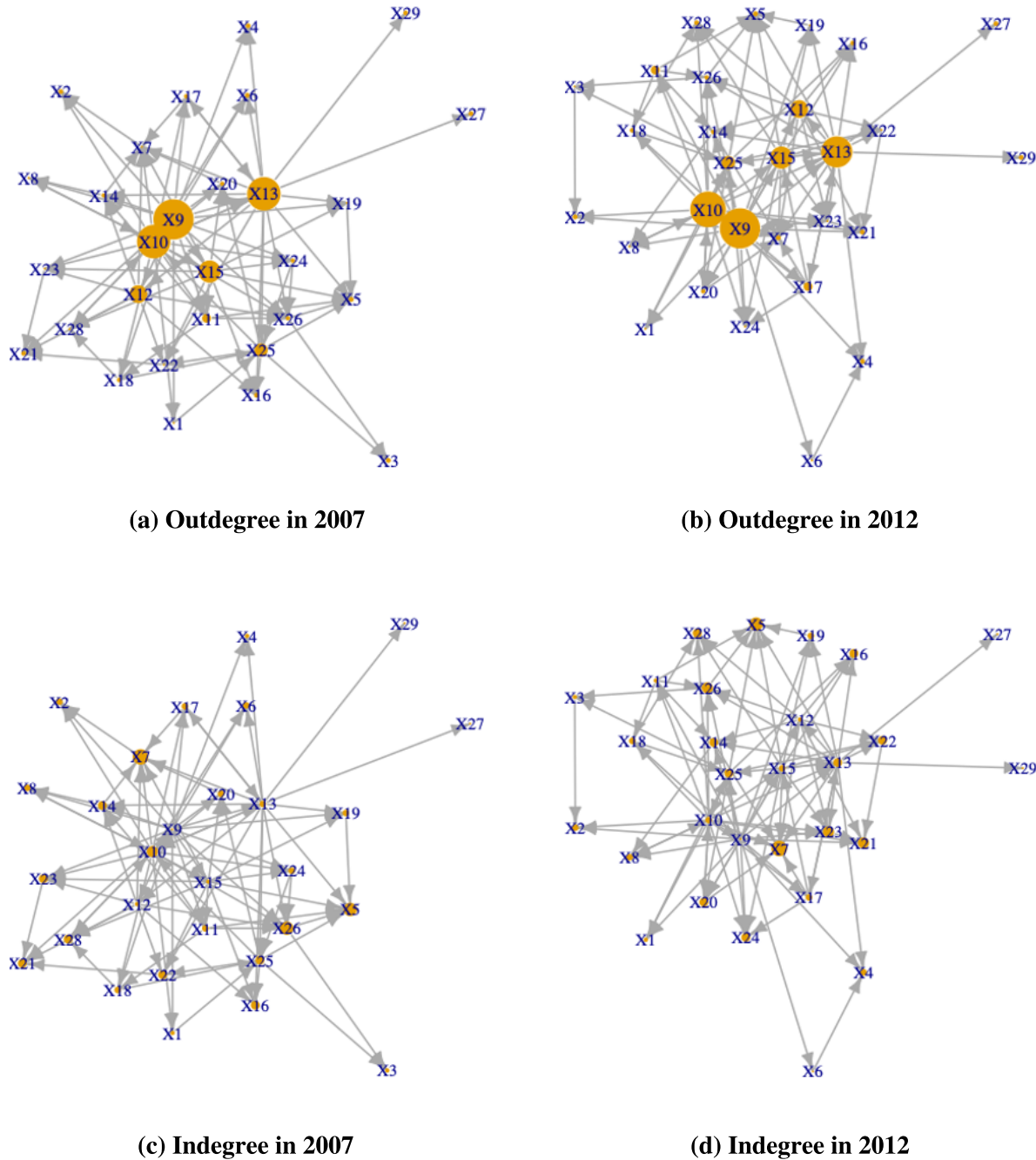
Table 1.
Network-wide measure for the network of Puerto Rico

Year	Diameter	Density
2007	5	0.218
2012	5	0.220

Source: author's own elaboration using data from the Puerto Rico Planning Board (2019) and (2023b).

However, other network measures help determine the role of sectors; Outdegree and Indegree are some of those measures; these results can be seen in Figure 4. For both years, it is possible to see that leading sellers (Outdegree) did not change at all; these sectors are Manufacturing (X9), Commerce (X10), Transportation (X11), Communications (X12), Finance and Insurance (X13), Technical and Professional Services (X15), and Food Services (X25). These sectors had a higher capacity to affect the economy if a supply shock occurred through them. Besides, these findings are similar to the results of Romero-Ramírez (2024), where the author estimated the Outdegree for the network of Puerto Rico from 1967 to 1992 and found that among the industries with higher Outdegree were Commerce, Communications, and Chemical Products (an industry that is part of the manufacturing sector). In the case of Indegree, it was impossible to identify the main buyers since all the sectors had similar Indegree levels; these results are also similar to the estimations of Romero-Ramírez (2024), since for the Input-Output matrices of 1967 and 1972, the author found that all the industries had more or less the same Indegree. The following network measure that will be estimated is PageRank; these results are summarized in Table 2.

Figure 4.
Outdegree and Indegree in the network of Puerto Rico.

(a) Outdegree in 2007

(b) Outdegree in 2012

(c) Indegree in 2007

(d) Indegree in 2012

Source: author's own elaboration using data from the Puerto Rico Planning Board (2019) and (2023b).

As mentioned, PageRank helps determine the sector's importance in the network, but with a different perspective than Outdegree and Indegree. A sector under PageRank will be significant if the sectors connected to it are important buyers or sellers. These results are summarized in Table 2. Also, it was decided to estimate

the mean and median for every year; these descriptive statistics will serve as a limit, and any sector with a PageRank higher than the mean and median will be considered significant.

Table 2.
PageRank in the network of Puerto Rico.

Sectors	2007	2012
Agriculture (X1)	0.02	0.02
Mining (except Oil and gas) (X2)	0.07	0.05
Other Mining Products (X3)	0.04	0.04
Electricity and Irrigation Services (X4)	0.02	0.03
Natural Gas and Healthiness Services (X5)	0.07	0.07
Water and Sewer Services (X6)	0.02	0.02
New Construction (X7)	0.06	0.06
Building Repair and Maintenance (X8)	0.03	0.03
Manufacturing (X9)	0.02	0.02
Commerce (X10)	0.09	0.07
Transportation (X11)	0.02	0.02
Communications (X12)	0.02	0.02
Finance and Insurance (X13)	0.03	0.03
Real Estate (X14)	0.03	0.03
Technical and Professional Services (X15)	0.02	0.03
Business Management (X16)	0.03	0.03
Administrative Services (X17)	0.02	0.02
Waste Management Services (X18)	0.03	0.03
Educational Services (X19)	0.02	0.02
Social Services and Health Care (X20)	0.03	0.03
Arts and Sports Spectators (X21)	0.06	0.07
Museums and Historical Sites (X22)	0.03	0.03
Other Recreational Services (X23)	0.03	0.03
Housing Accommodation (X24)	0.02	0.03
Food Services (X25)	0.06	0.07
Other Services (X26)	0.04	0.03
State Government (X27)	0.02	0.02
Municipal Government (X28)	0.04	0.04
Federal Government (X29)	0.02	0.02
Non-classifiable products industry (X30)	0.00	0.00
All Sectors Mean	0.03	0.03
All Sectors Median	0.03	0.03

Source: author's own elaboration using data from the Puerto Rico Planning Board (2019) and (2023b).

In Table 2, since the mean and median are 0.03, there are nine sectors with a PageRank higher than 0.03; these sectors are Mining (except Oil and gas) (X2), Other Mining Products (X3), Natural Gas and Healthiness Services (X5), New Construction (X7), Commerce (X10), Arts and Sports Spectators (X21), Food Services (X25), Other Services (X26), and Municipal Government (X28). These sectors are significant because they are connected with important buyers or sellers in Puerto Rico's network for 2007 and 2012. From these results, it is possible to make a few comments: The New Construction (X7) sector has a PageRank of 0.06 for 2007 and 2012; this "high" value of PageRank can be one of the drivers of the economic growth that Puerto Rico has experienced after Hurricane María in 2017, and it is forecast to continue for various years since Puerto Rico will receive approximately $76.4 billion to finance the reconstruction (Fuentes, 2022).

Also, in Table 2, it is possible to see that Arts and Sports Spectators (X21) had a PageRank of 0.06 in 2007 and 0.07 in 2012. Therefore, this is a critical sector in Puerto Rico's economy since it is connected to significant buyers and sellers in the network. However, the Department of Economic Development and Commerce of Puerto Rico, in its strategic framework for economic development named *PRopósito*, has not defined any strategy that could stimulate the growth of this sector either in Puerto Rico's internal market or its connections with external markets. This has happened despite Puerto Rican music, such as Reggaeton, being one of the most popular music genres in the world; since this genre has recently taken over the global music industry through Billboard charts and TikTok, with artists like Bad Bunny breaking records on platforms like Spotify. Consequently, it is essential to rethink how Puerto Rico and this sector can take advantage of the exposure Puerto Rican music and culture has experienced in recent years through the global mainstream music industry. It is possible to rethink industrial, fiscal, and regulatory policies regarding this sector that can contribute to economic growth.

Besides, it is essential to talk about the results for Municipal Government (X28); in 2016, the US Congress approved PROMESA; as part of this act, it was established that the FOMB would be in charge of the restructuring negotiations of the public debt. However, the FOMB has also been responsible for developing the government's budget. Through this responsibility, the FOMB has implemented a series of austerity policies that have affected various Puerto Rico's government units. For example, as part of this austerity package, the budget for municipal governments experienced a reduction of 44.3% in the fiscal year of 2018 (Meléndez, 2018), and these policies continued in the following years. These decisions regarding fiscal policy were made without considering the role and importance of the Municipal Government (X28) sector in Puerto Rico's network. Our estimations suggest that the FOMB affected the capacity to supply and demand services of one of the nine sectors with a higher PageRank in Puerto Rico's network; in other words, the FOMB's policies affected a sector connected to important buyers and sellers in the island's economy. Therefore, it is necessary to rethink fiscal policies regarding this sector.

It is essential to note that Mining (except Oil and gas) (X2) and Other Mining Products (X3) had a higher PageRank measure despite not being considered a historically significant sector in Puerto Rico's economy. These sectors have never been considered significant because employment in them represents a lower percentage of total employment. Besides, Figure 4 shows that these sectors do not have significant Outdegree and Indegree measures. However, PageRank presents a different approach; under this perspective, Mining (except Oil and gas) (X2) and Other Mining Products (X3) are significant because they are connected in Figures 4 and A3 to Manufacturing (X9), Commerce (X10), and Food Services (X25) and these last three sectors had significant Outdegree measures. In other words, the PageRank measure suggests the significance of a given sector through the quality of its connections and not through the quantity of the number of connections.

Also, from our results in Figure 4, Manufacturing (X9) was one of the prominent sellers in the network, but it was not a significant buyer. Table 2 provides another perspective for this sector; from the PageRank

measure, the Manufacturing (X9) sector was not connected to significant buyers or sellers. Therefore, this sector satisfied the demand of various sectors of the Puerto Rican economy, but those that demanded Manufacturing (X9) goods were insignificant sectors from the Outdegree and Indegree perspective. The last measure estimated was Betweenness Centrality; through this measure, it was possible to identify the communities or sub-networks within the Puerto Rico network. These results can be seen in Figure 5.

Figure 5.
Communities in the network of Puerto Rico.
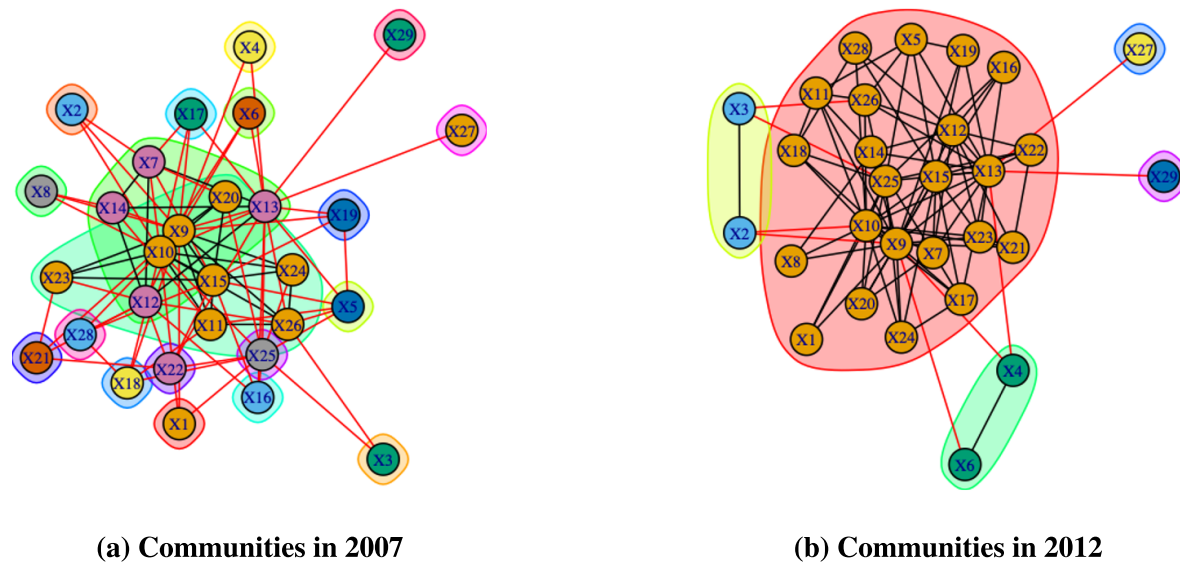
(a) Communities in 2007 **(b) Communities in 2012**

Source: author's own elaboration using data from the Puerto Rico Planning Board (2019) and (2023b).

Figure 5 presents two entirely different realities; in the case of 2007, it can be seen two communities, one of which is made of New Construction (X7), Communications (X12), Finance and Insurance (X13), and Real Estate (X14). The other community of 2007 is made of Manufacturing (X9), Commerce (X10), Transportation (X11), Technical and Professional Services (X15), Social Services and Health Care (X20), Other Recreational Services (X23), Housing Accommodation (X24), and Other Services (X26). While the other sectors in 2007 were isolated from the two communities. In the case of 2012, Figure 5 presents one "big" community with most of the sectors in it, two "small" communities, and two isolated sectors. One of the "small" communities is made up of Mining (except Oil and gas) (X2) and Other Mining Products (X3). Besides, the other "small" community in the 2012 network consists of Electricity and Irrigation Services (X4) and Water and Sewer Services (X6), and the State Government (X27) and the Federal Government (X29) are the two isolated sectors. It is possible that the two communities in the network of 2007 merged in 2012 due to the economic growth rate of 0.5% that Puerto Rico experienced during the fiscal year 2012 and the fiscal stimulus the island received in the aftermath of the Global Financial Crisis of the late 2000s. Consequently, a higher fragmentation in the communities during 2017 is expected. Additionally, the fact that most sectors are in the same community in 2012 could be a good characteristic, but it is also dangerous. For example, the transmission mechanisms could be faster when the economy receives a fiscal stimulus or experiences a negative shock.

CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper is an extension of the work of Romero-Ramírez (2024) since the author studied the productive structure of Puerto Rico during the second half of the 20th century, and our study focused on the post-2006 era. By using Input-Output data for 2007 and 2012, it was found that the transactions between sectors barely experienced growth, which can be explained by the fiscal stimulus Puerto Rico's economy received after the Global Financial Crisis (Quiñones-Pérez and Seda-Irizarry, 2020). Besides, it was found that the leading sellers in the network were Manufacturing (X9), Commerce (X10), Transportation (X11), Communications (X12), Finance and Insurance (X13), Technical and Professional Services (X15), and Food Services (X25). In addition, it was impossible to determine the sectors with the role of main buyers since all the sectors have more or less the same level of Indegree. Also, this paper introduces the PageRank measure for the study of the economy of Puerto Rico; through this measure, it was possible to identify the key sectors on the network but from a different perspective than Outdegree and Indegree.

Under PageRank, a sector is considered significant if the sectors connected to it are important sellers or buyers. The sectors with high PageRank values were Mining (except Oil and gas) (X2), Other Mining Products (X3), Natural Gas and Healthiness Services (X5), New Construction (X7), Commerce (X10), Arts and Sports Spectators (X21), Food Services (X25), Other Services (X26), and Municipal Government (X28). Also, the Betweenness Centrality measure made it possible to identify the communities within the network. For 2007, two communities were identified. Our first community was made up of New Construction (X7), Communications (X12), Finance and Insurance (X13), and Real Estate (X14), and the second community was made of Manufacturing (X9), Commerce (X10), Transportation (X11), Technical and Professional Services (X15), Social Services and Health Care (X20), Other Recreational Services (X23), Housing Accommodation (X24), and Other Services (X26). In the case of 2012, most of the sectors were together in the same community.

The main limitation of this paper was that the Puerto Rico Planning Board has not published the Input-Output matrix for 2017, although it is expected to be published in a few years. With that matrix, it will be possible to study the characteristics of the productive structure once the federal grants return to their average value after the Global Financial Crisis of 2007-2008. Besides, the qualitative Input-Output and Network Analysis techniques used in this paper could be used to study other Input-Output structures, either at the international level or the domestic economies of any country.

As mentioned, Puerto Rico is in a dangerous economic situation. Since the economy seems to be in the middle of a federal grants bubble, and public authorities already concluded the restructuring process of most of the public debt without a clear and defined industrial policy that can lead to economic growth in the long term. In general terms, the characteristics of the structure presented in this paper can be used to define policy intervention regarding industrial, regulatory, and fiscal topics that are well-defined and are not focused on a single strategy. However, here are a few policy recommendations:

As mentioned before, historically, Manufacturing (X9) has been one of the most critical sectors in the economy of Puerto Rico; however, through this sector, the economy of the island has experienced a deep deindustrialization, which is evident in Figure A4 of the appendix (Caraballo-Cueto and Lara, 2018; Romero-Ramírez, 2023c). Despite that reality, Manufacturing (X9) remains one of the sectors with higher employment levels on the island. Besides, through Figure A5 of the appendix, it can be seen that this sector contributes more than 40% to the overall GDP of Puerto Rico. Consequently, it is a crucial sector despite deindustrialization. Additionally, our results in Figure 4 allow us to conclude that Manufacturing (X9) was one of the prominent sellers in the network but not a significant buyer. Also, the results of the PageRank measure

in Table 2 suggest that Manufacturing (X9) was not connected to significant buyers or sellers; in consequence, this sector satisfied the demand of various sectors of the Puerto Rican economy, but those that demanded Manufacturing (X9) goods were insignificant sectors. This reality could imply that Manufacturing (X9) has lower spillover effects through Input-Output connections and that a significant part of the inputs that this sector needs to produce their outputs are imported. Therefore, it is recommended that the Department of Economic Development and Commerce of Puerto Rico establish an import substitution strategy for the different industries within the Manufacturing (X9) sector. Through this strategy, Manufacturing (X9) can increase its links with the island's economy through purchases (Indegree); this strategy could also stimulate economic activity and create new direct and indirect jobs. However, any well-designed industrial policy should not only be based on stimulating Manufacturing (X9) since one of the elements of the economic collapse experienced in Puerto Rico after 2006 is that the vast majority of economic strategies were only focused on the Manufacturing (X9) sector. In other words, diversifying the productive structure's core components is essential.

Besides, as shown through this paper, improving the quantity and quality of the National Accounts of Puerto Rico is necessary. For example, in Figures 1 and 2, the series were deflated using the 1954 GNP deflator, and currently, the National Accounts are only available on an annual frequency. However, the Puerto Rico Planning Board is working on a project to generate the National Accounts with a quarterly frequency. Also, since the most recent Input-Output matrix published by the Puerto Rico Planning Board is from 2012, it is necessary to establish an effective work plan and allocate the necessary budget resources to improve the quantity, quality, and timely publication of the National Accounts.

Another aspect that needs to be improved is related to the policy evaluation. For example, as mentioned before, the Department of Economic Development and Commerce of Puerto Rico published a framework for economic development named *PRopósito*; this framework has many flaws mentioned before. However, there is another significant flaw; in this framework, the agency identified six strategic sectors: Biosciences, Aerospace, Information Technology, Agribusiness, Tourism, and Emerging Sectors (DDEC, 2022). Nevertheless, it is unknown how these sectors were identified, the criteria for selecting them, and whether they can stimulate other sectors, transmit the received impulses, be integrated with the local network, participate in an import substitution strategy, and be significant exporters. Therefore, mechanisms of public policy evaluation must be established by the Government of Puerto Rico.

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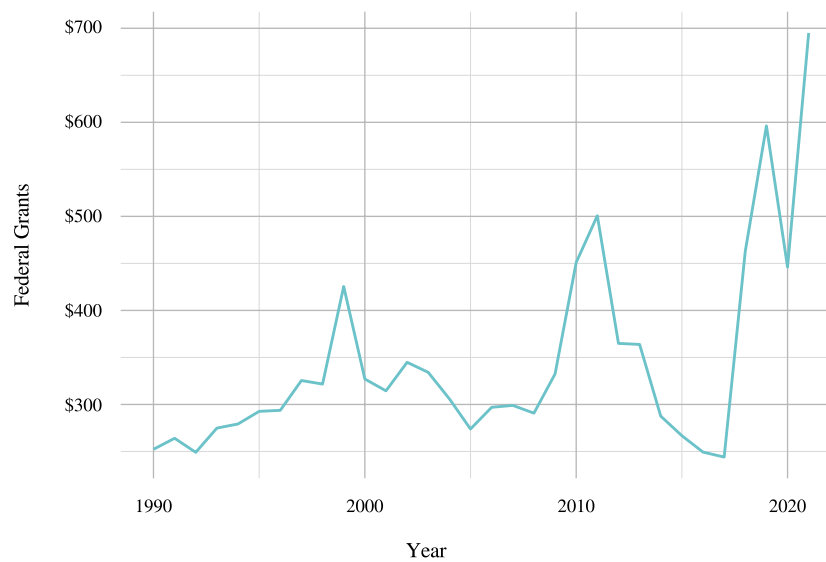
APPENDICES

Figure A1.
Gross National Product of Puerto Rico at constant 1954 prices
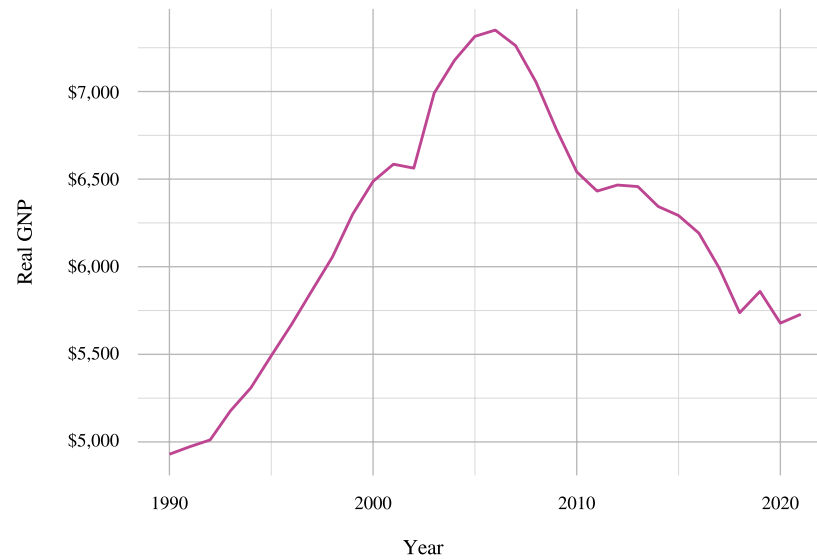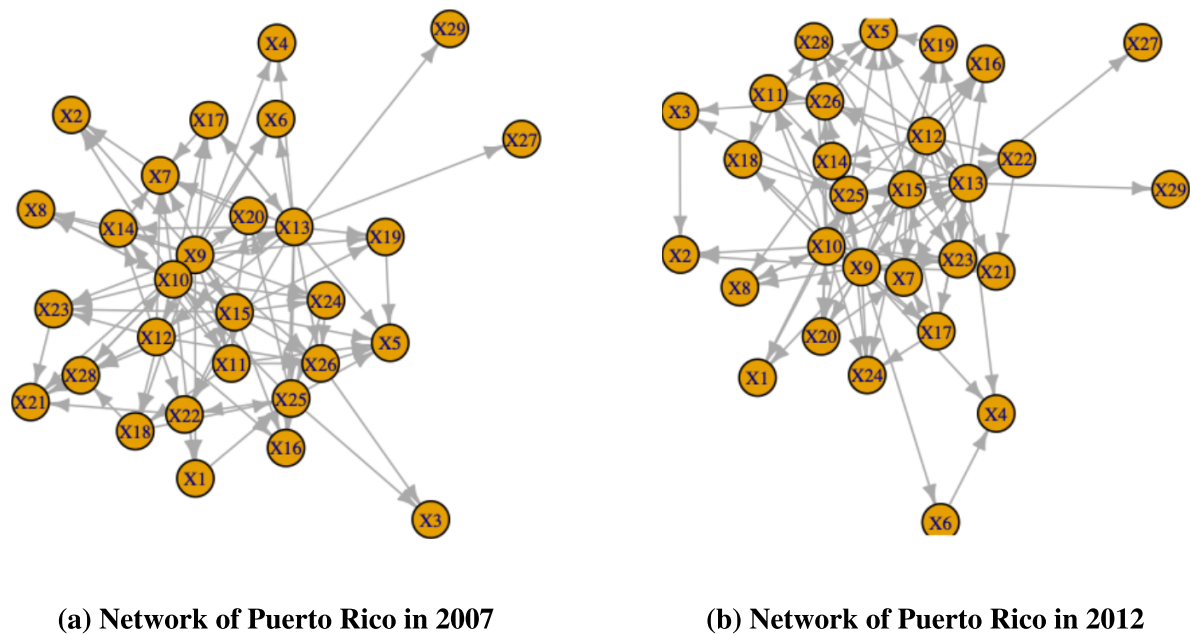
Real GNP

Source: author's own elaboration using data from the Puerto Rico Planning Board (2023a).

Figure A2.
Federal Grants of Puerto Rico at constant 1954 prices

Federal Grants

Source: author's own elaboration using data from the Puerto Rico Planning Board (2023a).

Figure A3.
Network of Puerto Rico

(a) Network of Puerto Rico in 2007 **(b) Network of Puerto Rico in 2012**

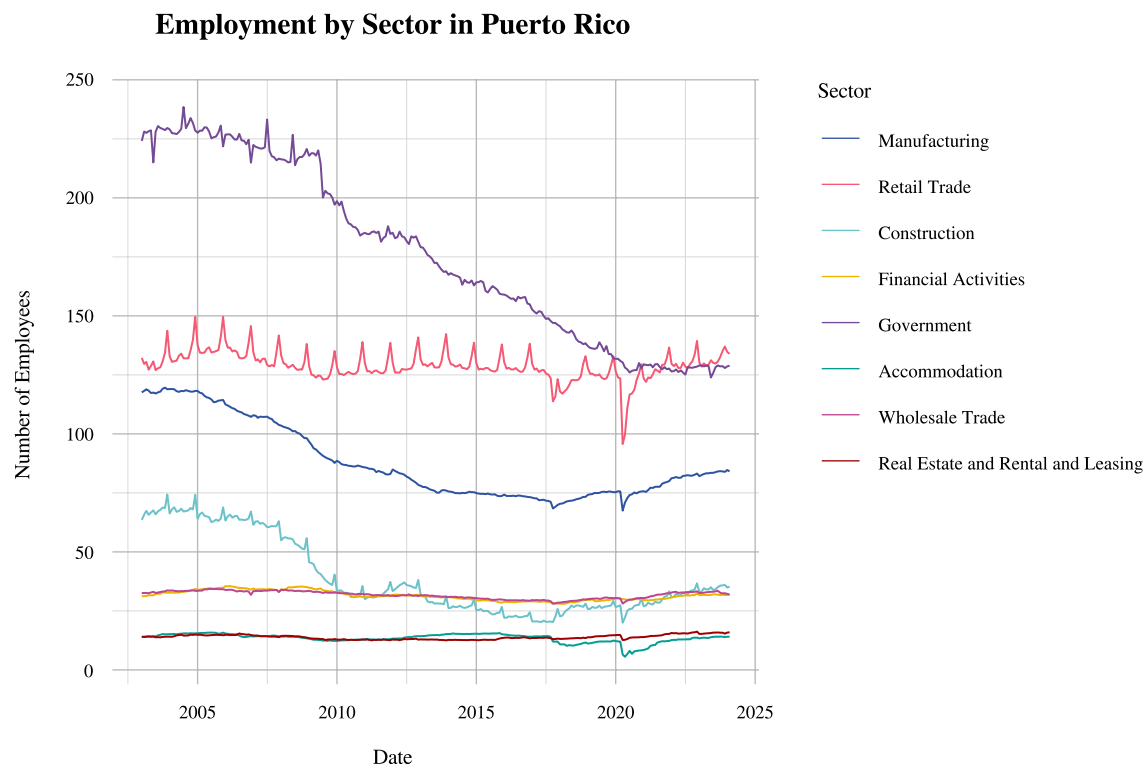**Source**: author's own elaboration using data from the Puerto Rico Planning Board (2019) and (2023b).

Table A1.
Codes assigned to sectors

Sectors	Codes
Agriculture	X1
Mining (except Oil and gas)	X2
Other Mining Products	X3
Electricity and Irrigation Services	X4
Natural Gas and Healthiness Services	X5
Water and Sewer Services	X6
New Construction	X7
Building Repair and Maintenance	X8
Manufacturing	X9
Commerce	X10
Transportation	X11
Communications	X12
Finance and Insurance	X13
Real Estate	X14
Technical and Professional Services	X15
Business Management	X16

| *Sectors*	*Codes*
Administrative Services	X17
Waste Management Services	X18
Educational Services	X19
Social Services and Health Care	X20
Arts and Sports Spectators	X21
Museums and Historical Sites	X22
Other Recreational Services	X23
Housing Accommodation	X24
Food Services	X25
Other Services	X26
State Government	X27
Municipal Government	X28
Federal Government	X29
Non-classifiable products industry	X30

Source: author's own elaboration.

Figure A4.
Selected Employment by Sector in Puerto Rico

Source: author's own elaboration using data from the U.S. Bureau of Labor Statistics & Federal Reserve Bank of St. Louis (2024).

Figure A5.
Manufacturing, Value Added (% of GDP) - Puerto Rico.
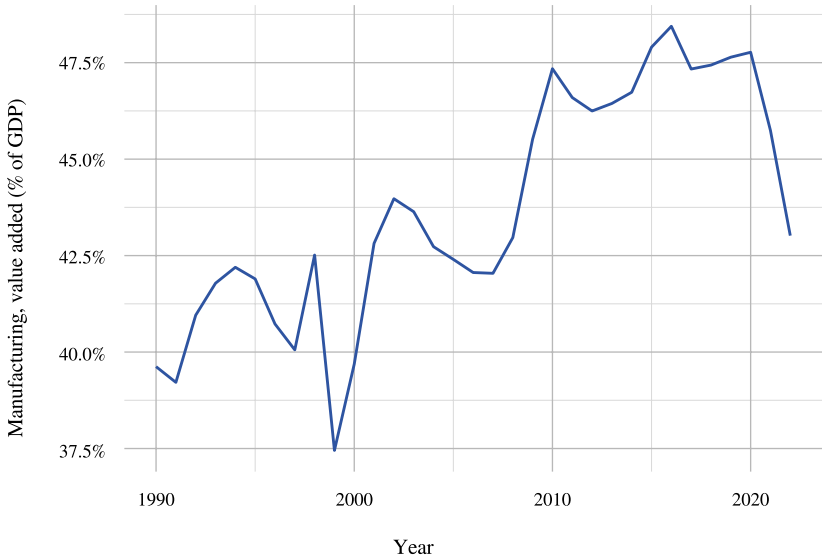
Source: author's own elaboration using data from the World Bank (2024).