THE EVOLUTION OF THE ECONOMY OF PUERTO RICO DURING THE POST-WAR: A NETWORK ANALYSIS

LA EVOLUCIÓN DE LA ECONOMÍA DE PUERTO RICO DURANTE LA POSGUERRA: UN ANÁLISIS DE REDES

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Resumen: Este trabajo estudia la evolución de la estructura productiva de Puerto Rico entre 1967 y 1992. Para examinar la evolución se utilizaron técnicas de Insumo-Producto y Análisis de Redes, que permitieron ilustrar las relaciones significativas en la estructura. Se estimó el Diámetro y la Densidad, y se encontró que la actividad económica aumentó entre 1967 y 1977. Sin embargo, entre 1982 y 1992 la actividad económica disminuyó. Además, se encontró que Electricidad y Productos Químicos tenían medidas significativas de *Outdegree* pero tenían medidas mínimas de *Indegree*, por lo que compraban pequeñas cantidades del resto de la economía.

Abstract: This paper studies the evolution of the productive structure of Puerto Rico between 1967 and 1992. In order to examine the evolution, Input-Output, and network analysis techniques were used, which allowed us to illustrate the significant relationships in the structure. Diameter and Density were estimated, and it was found that economic activity increased between 1967 and 1977. However, between 1982 and 1992, economic activity decreased. In addition, it was found that Electricity and Chemical Products had significant *Outdegree* measures but had minimal *Indegree* measures, so they bought small amounts from the rest of the economy.

1. Introduction

With the end of World War II, the economy of Puerto Rico began to evolve and transform. The evolution arose from increased investments in manufacturing from the United States of America (us), which caused the Puerto Rican economy to experience significant economic growth from the 1950s until the beginning of the 1970s (Toledo, 2006). Growth came to have an average annual growth rate of 4.9%, but with the oil embargo of 1973, the economy entered a period of significant economic stagnation (Rodríguez and Toledo, 2007). Luciano (2005) adds that the period from 1974 to 1999 was characterized by stagnation and economic instability, and the first element of instability was the increases in oil prices from 1973 to 1974. In this context, Puerto Rico experienced its first fiscal crisis since, by 1974, the government experienced its first unconstitutional budget deficit (Quiñones-Pérez and Seda-Irizarry, 2016).

Then, in the mid-1970s, the us Congress approved a special tax regime for us corporations under Section 936 of the Internal Revenue Code. According to Caraballo-Cueto and Lara (2018), by the height of the Section 936 bonanza, manufacturing represented 42% of Puerto Rico's Gross Domestic Product (GDP), created more than 30% of deposits in the local financial system, and represented 17% of total employment. Despite the importance of the different phases of industrialization in Puerto Rico, there are criticisms of the invitation-based industrialization model.

Luciano (2005) points out that for many economists, the cause of instability is the exhaustion of the development model. The author argues that some economists attribute the instability mainly to the deterioration of the comparative advantages that Puerto Rico had and the us recession during the 1970s. In contrast, other economists attribute the instability to the flight of capital (profits leaving the island), dependence on raw materials, expensive energy sources, and an economy oriented to external markets with minimal ties to internal markets (Luciano, 2005). Quiñones-Pérez and Seda-Irizarry (2020) add that industrial policies and a sustainable development model that satisfies Puerto Ricans' needs throughout this period of industrialization for export purposes have not been well defined.

The criticisms against the development model and industrialization initiatives for export purposes make Puerto Rico a good case to know: How did the productive structure of Puerto Rico evolve from 1967 to 1992? This paper aims to determine how the productive structure of Puerto Rico evolved from 1967 to 1992. In addition, it aims to analyze and evaluate inter-industrial relations in the economy of

Puerto Rico. As a hypothesis for this study, Puerto Rico's productive structure should have evolved into a denser and more complex network of relationships over time until reaching the period of stagnation and instability during the 1970s.

Knowing how the productive structure has evolved during the period mentioned above would serve to evaluate a large part of the economic policies established by the different administrations in Puerto Rico, particularly initiatives focused on stimulating growth and development through industrialization. Techniques of the Input-Output model and Network Analysis will be used. Therefore, another contribution is that this paper is the second study to apply qualitative Input-Output techniques and the first to use Network Analysis techniques in the economy of Puerto Rico. The first study that used qualitative Input-Output was carried out by Luciano (2005), but the analysis of this paper will add new network measures that were not used by the author above. In addition, the matrices used in this study have larger dimensions than those that Luciano (2005) used.

This paper is organized as follows: the second and third sections present a literature review on the economy of Puerto Rico during the post-war period and the methodological literature review; the fourth and fifth sections present the methodology used in this paper and the results; the sixth section discussed the conclusions and policy recommendations.

2. The economy of Puerto Rico during the post-war period

During the beginning of the industrialization program in Puerto Rico, manufacturing factories were operated by the government; these factories were focused on cement, ceramics, shoes, cardboard, and glass, among others (González, 1967; Ruiz, 1981). These factories were later sold to the private sector, and incentive policies for foreign capital were established (González, 1967). Therefore, the Government of Puerto Rico stopped producing goods to become an intermediary for private foreign capital (Villamil, 1981).

These strategies became known as industrialization by invitation (Ruiz, 1981). According to Bhatia (1960), the industrial tax exemption program was established in Puerto Rico in 1954 and attracted significant foreign investment. In addition, the author points out that this program managed to build an economy of processing imported products and then exporting those products. Then, a promotion campaign was established in the US to attract investment, which turned

Puerto Rico into an example of development for the rest of the world (González, 1967; Villamil, 1981). In this context, between 1948 and 1965, 8 255 new factories were established in Puerto Rico, and most of these new factories were foreign (González, 1967). Although this initiative had some degree of success regarding the number of factories established, it was not successful in the net employment generated since this was insignificant (Villamil, 1981).

From the 1960s, industrial strategies were reorientated to stimulate corporations with a high capital content, such as petrochemicals, pharmaceuticals, electrical and non-electrical machinery, and metals (Ruiz, 1981). The petrochemical corporations established on the island used imported oil and provided inputs for many industrial processes. These initiatives were based on the belief that having industrial inputs would stimulate forward linkages and generate new industries, which did not occur in Puerto Rico (Villamil, 1981).

According to Quiñones-Pérez and Seda-Irizarry (2016), during the 1970s, the oil embargo and its effects on the economy of Puerto Rico helped make invisible the signs of the exhaustion of the Puerto Rican economic model. In addition, the authors point out that the industrialization strategies had significant flaws, among which improvisation can be found. With improvisation, development strategies were absent, and industrial policies were simply based on taking advantage of temporary opportunities, which did not consider a long-term vision and relationships between the various sectors. Therefore, Puerto Rico was established as an enclave economy in which the stimulated industries did not have significant relationships with the rest of the economy (Quiñones-Pérez and Seda-Irizarry, 2016).

It is in this context that under the Tax Reform Act of 1976, Section 936 was created; the purpose of this section was to promote the investment of us corporations in us territories, and these corporations received full credit for the income resulting from their investments in the territories (Feliciano, 2018). Also, it is essential to note that the arrival of Section 936 placed manufacturing as the primary production sector on the island (Toledo, 2006). The electronics, medical devices, pharmaceutical, and chemical products industries are in this manufacturing sector (Caraballo-Cueto and Lara, 2018; Quiñones-Pérez and Seda-Irizarry, 2016; Alemar and Rodríguez, 2021).

One of the main criticisms of Section 936 and industrialization by invitation is that significant supply and demand links with the economy of Puerto Rico were not established. However, Luciano (2005) argues that the discussion about weakening linkages in the Puerto Rican economy has been debated only with informal arguments. The author

identified significant relationships among different sectors and found that most relationships are concentrated mainly in services, followed by manufacturing, mining, and construction sectors. This observation indicates that between 1972 and 1982, the system became more complex. Nevertheless, by 1987, the opposite trend happened. In addition, when comparing the internal structure of Puerto Rico with that of the US, the author found that the Puerto Rican structure was more complex than the American one. Also, the author found that in terms of relations with the US, manufacturing was the one that presented the most significant relations (Luciano, 2005). Besides, Lara and Rivera (2005) point out that when using data on imports as a percentage of GDP between 1950 and 1983, manufacturing companies decreased their linkages with the rest of the economy. The authors also point out that when updating the analysis with data from 2003, it can be concluded that those linkages continue to decrease.

The criticisms above (and others) of Section 936 led to its elimination in 1996, and a 10-year transition period was established, ending in late 2005 (Lawrence and Lara, 2006; Feliciano, 2018). However, some tax benefits remained in Puerto Rico because the companies could be incorporated as Controlled Foreign Corporations (CFC). The CFCs received benefits that were granted to US corporations that operated in foreign jurisdictions; under this scheme, the corporations could retain the difference between the taxes they paid in the US and the taxes they paid in Puerto Rico (Lawrence and Lara, 2006); for which through the CFCs tax benefits the island had specific "tools" to attract investment after the elimination of Section 936.

According to Quiñones-Pérez and Seda-Irizarry (2021), there are several main observations about the elimination of Section 936 and the economic depression experienced by Puerto Ricans during the 21st century. The first concern is that since the 1990s, employment and industrial companies have decreased. In addition, some point out that public debt has increased since the 1990s and that in the mid-2000s, when the phase-out period ended, the economic depression began in Puerto Rico (Quiñones-Pérez and Seda-Irizarry, 2021).

Caraballo-Cueto and Lara (2018) point out something similar since they found that the indebtedness of the Government of Puerto Rico can be connected to the decrease in manufacturing employment that the island suffered. In other words, deindustrialization led to an increase in public sector indebtedness. In contrast, Quiñones-Pérez and Seda-Irizarry (2021) propose another perspective on the crisis in Puerto Rico. The authors point out that the Commonwealth of Puerto Rico crises and the economic model are intertwined but

must be conceptually analyzed separately. Under this analysis, it is considered that the collapse of the Commonwealth and the collapse of the economic model, or rather the collapse of one into the other, hides the internal power relations at stake in Puerto Rico.

These relationships have been the ones that have designed the responses to the economic crisis and can explain the neoliberal adjustment program that has been established to address the crisis. Within these power relationships, the role of specific individuals or groups that have benefited during the current Puerto Rican crisis can be highlighted because business organizations promoted conservative policies in favor of the free market while defending their corporate well-being (Quiñones-Pérez and Seda-Irizarry, 2021).

In summary, since the post-war, the transformations of Puerto Rico's economy were based on industrialization for export purposes dependent on foreign capital, mainly American. This industrialization process can be divided into several phases. The first focused on clothing; the second focused on heavy industries, particularly refining and petrochemical, and finally, pharmaceutical and electronics (Quiñones-Pérez and Seda-Irizarry, 2016). Besides, Villamil (1981) points out that the government stopped participating in the production processes of goods to play the role of intermediary for foreign capital that arrived on the island by invitation. Since the government sought to attract foreign manufacturing corporations by offering tax incentives (Caraballo-Cueto, 2021), in other words, during industrialization by invitation, foreign direct investment was attracted through various incentives without clear objectives.

3. Methodological literature review

In economic analysis, many methodologies try to provide answers to economic phenomena. Within these methodologies, qualitative and quantitative approaches can be found. Within the economic phenomena in a regional context, the following methodologies can be found: Gravitational models, Spatial Econometrics, Integrated models of Econometrics with Input-Output and Input-Output models. All these methodological approaches have different characteristics; however, this literature review will focus on the Input-Output Analysis and some qualitative approaches.

According to Miller and Blair (2009), the Input-Output model was developed by Wassily Leontief, and for this contribution, he received the Nobel Prize in Economics in 1973. In addition, the authors

point out that the Leontief model is generally built from data from a specific geographic space. In general terms, the model refers to the activity of specific industries that produce goods and are consumers of goods produced by other industries during the process of producing their goods (Miller and Blair, 2009). Furthermore, these models' theoretical basis cannot be separated from the framework and is a general equilibrium model (Luciano, 2005). Meanwhile, Molina (2017) points out that through these models, the structure of an economy can be studied and analyzed.

When considering the characteristics of the different models used in regional economic analysis and the objectives of this paper, it was decided to use the Input-Output model. This decision was made because this methodological approach allows knowing sectoral information and serves as a descriptive tool of the economy that will be studied, in this case, that of Puerto Rico. However, quantitative approaches to Input-Output Analysis can fail to explain some aspects of an economic structure; that is, they have failed to describe the connections between sectors, which causes the connections not to be clearly understood (Aroche, 2003). While qualitative approaches present information that quantitative approaches cannot. Therefore, this study will focus on conducting an analysis similar to that proposed by Aroche (2003), where a technical coefficients matrix and a filter are used to create a binary matrix. Later, the binary matrix will be used to graph the significant relationships in the system.

However, there are other methodological approaches with objectives and purposes similar to qualitative Input-Output, one of the prominent examples being Network Analysis. This discipline is interdisciplinary since it has been used by social scientists such as sociologists and anthropologists and natural scientists such as computer scientists, mathematicians, and physicists (De Benedictis *et al.*, 2014; Aroche, 2003). This interdisciplinary evolution has led to the use of Network Analysis techniques to conduct econophysics projects to study international trade (Amador and Cabral, 2017).

There are even studies that have used network techniques for purely economic studies focused on international trade that use Input-Output matrices (Amador and Cabral, 2017; Pacheco, 2018; Vélez, 2020; Romero, 2022). In terms of measures, it is possible to mention that in the field of Network Analysis, some measures have been developed that allow studying the behavior of a network and the roles of those who participate in the network. For example, the Diameter and the Density allow us to know the growth of the network being studied. In contrast, Outdegree and Indegree suggest the role of countries or

industries in a network.

Density and Diameter have been proposed by Newman (2010) to study relationships within a context of binary matrices and, therefore, networks. Diameter and Density measurements have been used for many disciplines; for example, Salau *et al.* (2019) use these measures to study animal science networks. In the case of economics, these measurements were also estimated by Hao *et al.* (2016), Wang and Kong (2019), Xu *et al.* (2020), Vélez (2020), and Romero (2022) in their respective studies regarding international trade.

In the case of Outdegree and Indegree, it is essential to mention that they have also been applied in other disciplines unrelated to economics; for example, Ichinose *et al.* (2018) applied these measures to studies on networks in natural sciences. While in the case of economics, Outdegree and Indegree have been used for several studies, including Squartini *et al.* (2011), De Benedictis *et al.* (2014), Amador and Cabral (2017), Pacheco (2018), Vélez (2020), and Romero (2022).

In summary, the first part of the methodology will focus on aspects commonly used in qualitative Input-Output, as explained by Aroche (2003). The second part of the methodology will use techniques and measures of network analysis that have been used in other disciplines but which, in recent times, have begun to be used for Input-Output data.

4. Qualitative Input-Output and Network Analysis

This section will present qualitative Input-Output techniques and Network Analysis measures to illustrate structures, connections, and interactions. Pacheco (2018) argues that in Network Analysis, measures have been developed to evaluate the position of a vertex in a network. While Vélez (2020) points out that centrality measures aim to determine which vertices are more critical in a network. Therefore, centrality measures will help determine the most important industries in the network of Puerto Rico.

This qualitative analysis of the productive structure aims to know its core components regarding internal transactions (Luciano, 2005). The Input-Output matrices of Puerto Rico for 1967, 1972, 1977, 1982, 1987, and 1992 will be used to perform the proposed analysis. These matrices are aggregated into 44 and 43 industries and were published by the Puerto Rico Institute of Statistics (IEPR, 2017). The first step is to use the Technical Coefficients Matrix (A). In Matrix A, each element a_{ij} represents the proportion of merchandise from sector i

used as an input in producing a unit of merchandise from sector j. Matrix A is defined as:

$$A = \begin{vmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{vmatrix}$$

$$(1)$$

The next step is to use a filter that translates real numbers into binary numbers. Aroche (1993) uses a filter where n is the number of columns/rows in Matrix A, and in the case of this study, it represents the number of industries. Besides, the criterion of this filter to order the sectors at different levels is related to the final demand (Luciano, 2005). The filter of Aroche (1993) is defined as:

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

In equation (2), 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. Besides, the network will be built from Matrix W; this Matrix is defined as:

$$W = \begin{vmatrix} w_{11} & w_{12} & \dots \\ \vdots & \ddots & \\ w_{m1} & & w_{mm} \end{vmatrix}$$

$$(3)$$

In the Matrix W each element w_{ij} represents an edge between vertices i and j. Besides, each row serves as a list of the outgoing edges from the vertex of that row. In comparison, each column serves as a list of the incoming edges of the vertex of that column. In the case of this Matrix, the elements w_{ij} will be equal to 0 if there is no significant relationship between industries i and j. In addition, they will be equal to 1 if there is a significant relationship.

As mentioned above, several measures allow for identifying specific characteristics of the networks. Some of these measurements are Diameter and Density. Newman (2010) highlights that Diameter representes the number of edges that should be traversed to get from one end to the other end of the network. This measure helps determine how extensive the network is. Besides, the author argues that Density helps determine how tightly connected the network is; this measure can be defined as follows:

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

In the case of equation (4), m is the number of edges, and ρ is in the range of $0 \leq \rho \leq 1$. If ρ is equal to 0, the network has no edges; if it is equal to 1, the network is completely connected with the maximum number of edges (Vélez, 2020). This measure has the objective of measuring the economic activity in the network that is being studied. An increase in Diameter means that more industries participate in transactions, and an increase in Density is equivalent to an increase in transactions between industries. Additionally, the vertices in a network can be evaluated to measure degree. There are two-degree measures, Indegree and Outdegree, which can be defined as follows:

$$d_i^{out} = \sum_{j=1}^{N} \overrightarrow{w_{ij}} \text{ and } d_j^{in} = \sum_{i=1}^{N} \overrightarrow{w_{ij}}$$

$$\tag{5}$$

Vélez (2020) argues that Outdegree represents the outgoing edges and Indegree represents the number of incoming edges. An incoming edge is a significant purchase relationship of the industries under consideration. In comparison, the outgoing edges are a significant relationship for sales purposes. All the measures discussed in this section will allow us to know the significant relationships of the industries in the economy of Puerto Rico, their role in the relationships, and their changes over time.

5. Results

This section studies the productive structure of Puerto Rico. The analysis is done through qualitative Input-Output and Network Analysis techniques using aggregated matrices for 44 and 43 industries in 1967, 1972, 1977, 1982, 1987, and 1992. The industries were assigned a different code to facilitate the visualization of the networks. The codes and the industries' names appear in Appendix A. Besides, it is essential to mention that the general graphs of the Puerto Rico network are found in Appendix B of this paper.

Also, the R programming language was used to generate the visualizations and estimate the network measures. In addition to the graphs, other measures can be used to study the structure of transactions in Puerto Rico's economy; some of these measures are Diameter and Density. With the Diameter, the vertices between the ends of the network can be estimated, and Density helps determine how connected the network is.

Table 1
*Network-wide measure for the network of*
Puerto Rico (1967-1992)

Year	Diameter	Density
1967	6	0.132
1972	10	0.143
1977	11	0.173
1982	7	0.165
1987	7	0.133
1992	9	0.152

Source: Author's elaboration.

Table 1 summarizes some attributes of the Puerto Rico network and the transactions and relationships they illustrated. These results show that the Diameter and Density increased between 1967 and 1977. These results signify an increase in the economic activity in the Puerto Rico network during that decade. During this period, there was an increase in significant inter-industrial relations. In other words, purchases and sales in inter-industrial relations and total production experienced growth, constituting evidence of an economy with growth capacity. These results are consistent with the economic

growth rates of 4.9% that Puerto Rico experienced between the 1950s and the 1970s (Rodríguez and Toledo, 2007; Toledo, 2006). However, between 1982 and 1987, the Diameter and Density of the Puerto Rico network experienced a decrease.

Figure 1
Outdegree in the network of Puerto Rico (1967-1982)
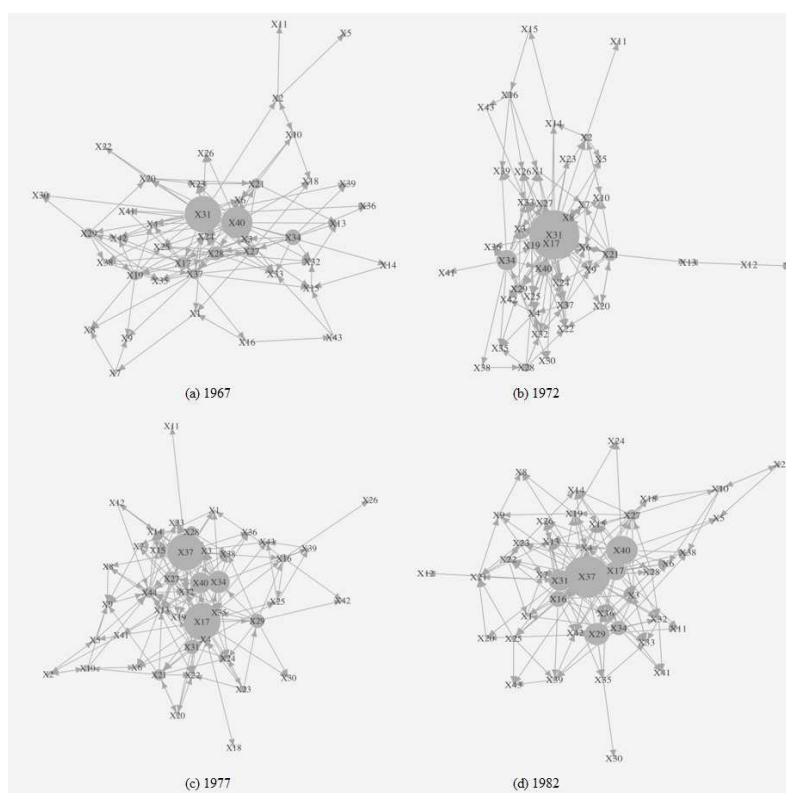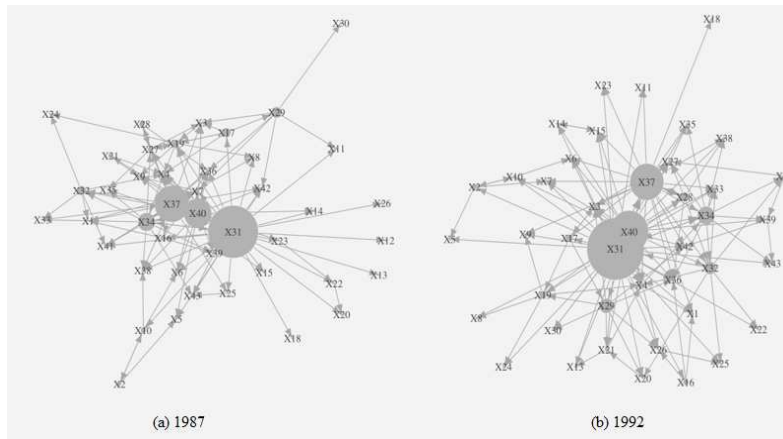

Source: Authors' elaboration.

These results mean economic activity decreased because fewer connections existed in those two years. In other words, the economy gradually lost its capacity for growth; this is manifested through a decrease in significant inter-industrial relations between the different industries of the Puerto Rican economy; these results can be explained by the economic stagnation and instability that characterized the 1980s, 1990s, and 2000s (Luciano, 2005; Fuentes-Ramírez, 2020). By

1992, the Diameter and Density increased to levels lower than in 1977. The instability of the 1990s can also explain these results. Another explanation may be associated with possible variations or changes in the methodology used to build and elaborate the 1992 Matrix.

However, other metrics can be used to examine the role of industries in the relationships. These metrics are Outdegree and Indegree. Figures 1 and 2 show the Outdegree results for the Puerto Rico network. In this case, the arrows emanating from the network represent a significant relationship in terms of sales.

These results show that Commerce (31) was the top seller for 1967, 1972, 1987, and 1992. For 1977 and 1982, Commerce (31) was not the industry that showed the largest Outdegree but was among the industries with a significant Outdegree. In the case of 1977, the prominent sellers were Oil refineries and products (17) and Commercial services (37); the latter industry was also the preeminent seller in 1982.

Figure 2
*Outdegree in the network of Puerto Rico (1987-1992)*

Source: Authors' elaboration.

Some industries that showed significant Outdegrees over time are Other services (40), Real estate (34), Communications (28), Oil refineries and products (17), Electricity (29), and Chemical products (16). In the case of Electricity (29), these results are curious since, based on the graphs in Appendix B, it would seem that Electricity (29) was moving away from the center of the network. Despite

this, Electricity (29) showed significant Outdegrees and was one of the prominent sellers in the Puerto Rico network. In the case of Chemical products (16), it can be concluded that this industry was never the prominent seller of the network. However, it appeared with a significant Outdegree practically every year. These results are important because there is debate over whether the industries that benefited from Section 936 had significant relationships with the rest of the economy. As previously discussed, Chemical products (16) are one of the industries associated with Section 936 (Alemar and Rodríguez, 2021). Therefore, these results acquire a critical relevance.

Figure 3 shows the Indegree for the Puerto Rico network between 1967 and 1972. The industries have more or less the same Indegree; therefore, it is impossible to differentiate who could be the primary buyer in both networks.

Figure 3
*Indegree in the network of Puerto Rico (1967-1972)*
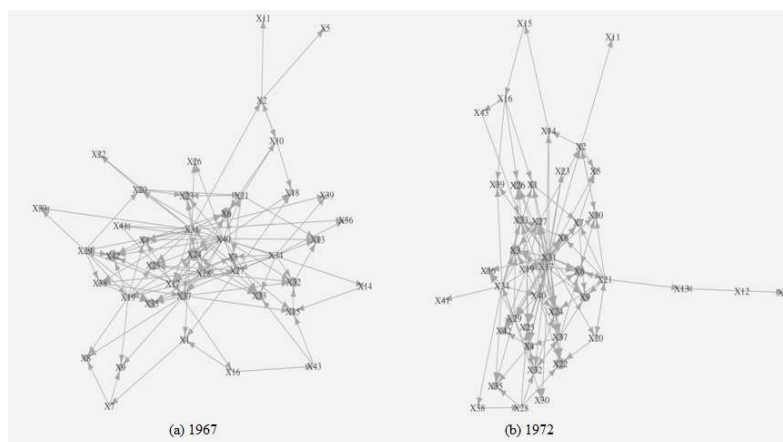
Source: Authors' elaboration.

However, for 1977, the scenario changes because the industries that show the highest Indegree are the Non-classifiable products industry (44), Banks and other credit agencies (32), Construction (4), Transportation equipment (24), and Machinery except electrical (22). These results imply those industries are the main buyers for 1977. Simultaneously, the remaining industries exhibit roughly similar Indegree values. For 1982, Personal Services (36), Mining (3), Municipal government (42), Printing and Publishing (15), and Wood and wood

products (13) showed the highest Indegrees. Therefore, between 1977 and 1982, the industries with the largest Indegrees and the main buyers changed utterly. In addition, the results of 1982 suggest that the rest of the industries possess relatively similar Indegree.

Figure 4
Indegree in the network of Puerto Rico (1977-1982)

(a) 1977   (b) 1982
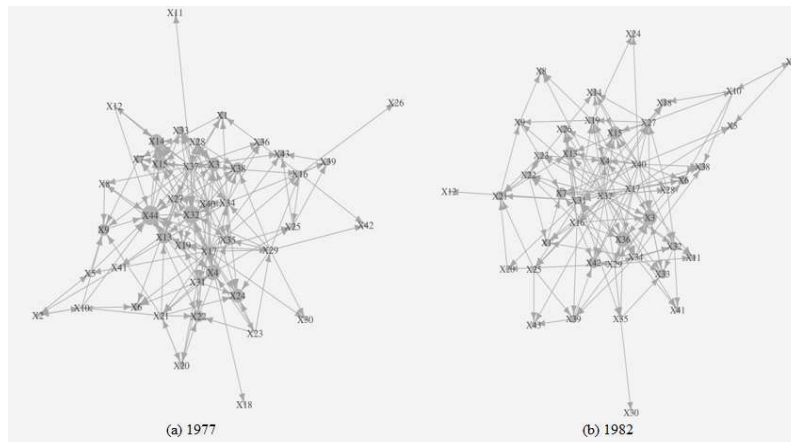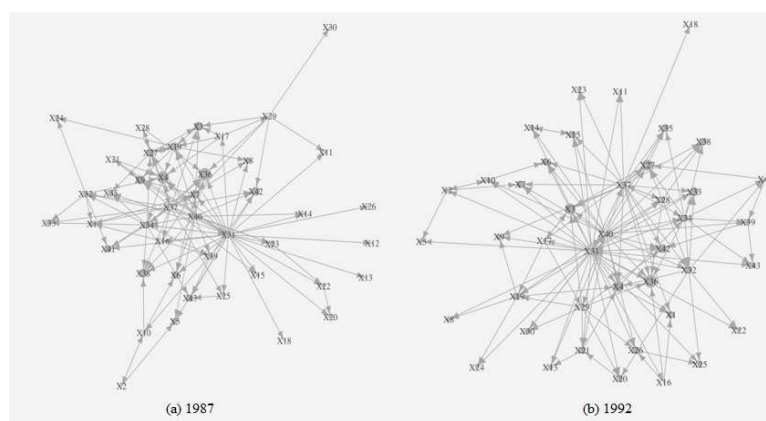
Source: Authors' elaboration.

Another important point about the graphs in figure 4 is that the Indegree of Electricity (29) and Chemical products (16) is minimal. The results for Electricity (29) could be explained by Puerto Rico's dependence on imported fossil fuels (O'Neill-Carrillo and Rivera-Quiñones, 2018). At the same time, the results for Chemical products (16) could suggest that this industry is an enclave, at least from an Indegree perspective. However, as mentioned above, Chemical products (16) had a significant Outdegree during almost all the years in figures 1 and 2. Therefore, this industry was one of the prominent sellers (although it was always far from being the main one).

Figure 5 shows the Indegree in the Puerto Rico networks for 1987 and 1992. In 1987 the industries that showed the highest Indegree were Construction (4), Personal services (36), Power plants, refineries, and candies (7). For 1992, the industries with higher Indegree were Personal services (36), Construction (4), Mining (3), Municipal government (42), and Transportation (27), which coincide with the results of some previous years.

Those industries that show the largest Indegree are the main buyers in the networks of 1987 and 1992. In the cases of the other

industries, they have nearly the same Indegree. Furthermore, it is essential to note that for 1987 and 1992 (as in 1977 and 1982), the Indegrees for Electricity (29) and Chemical products (16) are minimal.

Figure 5
Indegree in the network of Puerto Rico (1987-1992)

(a) 1987 (b) 1992

Source: Authors' elaboration.

In summary, the results of Diameter and Density coincide with the economic growth and instability/stagnation Puerto Rico experienced between 1967 and 1992. Therefore, these results should not be surprising. At the same time, the Indegree results for Chemical products (16) and Electricity (29) is expected since it is reported in the literature that these industries bought small amounts of intermediate inputs from the rest of the economy. In other words, they acquire crude oil and other intermediate inputs through imports. Besides, the Outdegree of Electricity (29) should not be surprising since this industry significantly supplies various sectors of the economy and provides an essential service for a large number of companies and personal consumption. In the case of Outdegree of Chemical products (16), these results are surprising since, from the sales side, this industry does not seem to behave like an enclave.

In addition, the results of Outdegree and Indegree show that long before the deindustrialization experienced in Puerto Rico since the late 1980s (Caraballo-Cueto and Lara, 2018), the economy showed signs that sectors not linked to manufacturing were becoming more critical. For example, it is evident in figures 1 and 2 that Commerce

(31) was increasingly important in the economy from the sales side (Outdegree). Something similar can be seen in figures 4 and 5 since among the industries that show greater importance from the buying side (Indegree), they are linked to many non-manufacturing industries such as Banks and other credit agencies (32), Construction (4), Personal Services (36), Printing and Publishing (15), among others; this could coincide with arguments that the model of industrialization by invitation was experimenting exhaustion.

6. Conclusions and policy recommendations

This paper showed that the economic structure of Puerto Rico became more complex and denser between 1967 and 1977 because, during this period, there were more significant relations in the network. These results mean higher economic activity through economic transactions in inter-industrial relations and are consistent with the economic growth that Puerto Rico experienced between the 1950s and 1970s (Rodríguez and Toledo, 2007; Toledo, 2006). However, between 1982 and 1987, the structure became less dense; hence, there were fewer economic transactions in inter-industrial relations. The stagnation and instability of the 1970s-2000s can explain these results (Luciano, 2005; Fuentes-Ramírez, 2020). In addition, in 1992 the structure became denser again but at lower levels than in 1977. These results could be explained by the instability or changes in the methods used to build the 1992 Matrix. Then it was possible to identify the most critical industries in the network through Outdegree and Indegree.

The results of Outdegree showed that during most of the period (1967-1992), Commerce (31) was the prominent seller or one of the most prominent sellers in Puerto Rico's economy. Other significant sellers in the productive structure were Commercial services (37), Other services (40), Real estate (34), Communications (28), Oil refineries and products (17), Electricity (29), and Chemical products (16). If a supply shock had occurred in these industries, the economy of Puerto Rico could have been deeply affected.

In the case of Indegree, it was found that between 1967 and 1972, it was impossible to identify which industry was the primary buyer because the industries in the network had more or less the same Indegree. Therefore, no industry presented characteristics that would suggest which was the most important from the buyer side. Furthermore, this means that no industry could significantly affect

the structure if a demand shock occurred in that particular industry. Between 1977 and 1992, a significant variation in the industries that showed higher Indegree was observed. However, some industries were repeated, such as Personal services (36), Construction (4), Mining (3), and Municipal government (42). The industries above were the ones that would have had the most significant capacity to affect the system had a demand shock occurred in those industries of the Puerto Rican economy.

This paper adds to the literature on Puerto Rico in different ways: While the literature on the economic model of Puerto Rico focuses on econometric or historical approaches (Caraballo-Cueto and Lara, 2018; Quiñones-Pérez and Seda-Irizarry, 2016); this paper considers a structural approach through mainly Network Analysis techniques. Our results suggest that Puerto Rico's economy was on a growth path until 1977. Besides, these results showed that before the deindustrialization experience since the late 1980s, non-manufacturing industries were more significant in the productive structure of Puerto Rico.

Besides, in sectoral terms, Electricity (29) showed a significant Outdegree, for which it was one of the network's leading sellers. However, upon examining the results of Electricity's Indegree, it can be seen that they are minimal. Therefore, this industry bought small amounts from the rest of the economy; these results showed the true nature of the behavior of Electricity (29) in Puerto Rico's economy, while the literature only suggests that Puerto Rico has a high dependence on imported fossil fuels (O'Neill-Carrillo and Rivera-Quiñones, 2018). In addition, our results suggest that Chemical products (16) were never in the center of the network but were not isolated, and this industry showed significant Outdegrees, although it was never a prominent seller in the networks. By comparison, Chemical products' Indegrees were found to be consistently minimal. Therefore, it never bought significantly from other industries in the Puerto Rican economy. These results could suggest that the Chemical products industry (16) is an enclave (at least from the Indegree perspective); this is consistent with Quiñones-Pérez and Seda-Irizarry (2016), who stated that the industries stimulated during industrialization by invitation, such as Chemical products (16), did not maintain significant relationships with the rest of the economy. Nevertheless, the Outdegree results of Chemical products (16) suggest this industry was not an enclave from this other perspective.

One of the main limitations was the absence of published Input-Output matrices that present inter-regional trade between Puerto

Rico and the US. If this limitation had not existed, it would have been possible to illustrate the significant relations between the two countries and, therefore, to know which industries have more significant ties with the island's economy and which have more significant ties with the US. Another limitation of this study is the reliance on outdated data, as the most recent matrix published for 44 and 43 industries dates back to 1992. Therefore, it was impossible to evaluate and analyze the evolution of Puerto Rico's economy during the elimination of Section 936. In this sense, future projects could expand this analysis if matrices of inter-regional trade and matrices to 44 and 43 industries after 1992 are published. Furthermore, the qualitative techniques in this paper can be used to study a country's internal economy or international trade relations.

Puerto Rico is currently in a dangerous economic situation. In 2022, the Debt Adjustment Plan of the Commonwealth of Puerto Rico was approved. Besides, like most countries in the world, in 2022, the island was affected by the ravages of inflation. Given this scenario, the Department of Economic Development and Commerce of Puerto Rico has published a strategic framework for economic development, which resembles several aspects of industrialization policies by invitation established since the end of World War II. Faced with the possibility of a new situation of insolvency in public finances or default, the mistakes from the past must not be made, especially concerning the industries associated with Section 936. Therefore, it is recommended to establish an industrial policy that is not improvised, has a long-term vision, and is not based on short-term opportunities. In addition, the incentivized industries must maintain strong links with the internal economy of Puerto Rico since maintaining higher links could maximize the benefits of an industrialization process, such as employment, income, technology transfer, managerial-business development, and internal capital formation, among other benefits.

For instance, in this regard, a reorientation of the Electricity industry (29) should be stimulated; this reorientation should have two purposes. The first is to depend less on fossil fuels and promote renewable energy sources. The reorientation will allow the economy to be less exposed to oil shocks in international markets and create an eco-friendlier economy. The second purpose is to stimulate new industries associated with generating renewable energy, for which the Electricity industry (29) could increase its links with the economy of Puerto Rico through purchases (Indegree). In addition, the incentives granted by the government must be accompanied by requirements and objectives associated with direct jobs generated and investment. Furthermore,

mechanisms of public policy evaluation must be established for the incentives granted, so that it can be measured whether the companies or individuals that receive the benefits are contributing to the growth and development of Puerto Rico's economy.

Acknowledgements

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Appendix A

Table A1
Codes assigned to industries

Industry	Code
Sugar cane	X1
Other agriculture	X2
Mining	X3
Construction	X4
Milk products	X5
Bakery products	X6
Power plants, refineries, and candies	X7
Alcoholic beverages and malts	X8
Non-alcoholic beverages	X9
Miscellaneous foods	X10
Tobacco products	X11
Clothing and textile products	X12
Wood and wood products	X13
Paper and paper products	X14
Printing and publishing	X15
Chemical products	X16

Table A1
(continued)

Industry	Code
Oil refineries and products	X17
Leather and leather products	X18
Stone, clay, and glass products	X19
Primary metal products	X20
Fabricated metal products	X21
Machinery, except electrical	X22
Electrical machinery	X23
Transportation equipment	X24
Professional instruments	X25
Miscellaneous manufacturing	X26
Transportation	X27
Communications	X28
Electricity	X29
Water, gas, and sanitary services	X30
Commerce	X31
Banks and other credit agencies	X32
Insurance	X33
Real estate	X34
Hotels and lodging houses	X35
Personal services	X36
Commercial services	X37
Fun and recreation	X38
Health services	X39
Other services	X40
State government	X41
Municipal government	X42
Federal government	X43
Non-classifiable products industry	X44

Source: Author's elaboration.

Appendix B

<div align="center">

Figure B1
Network of Puerto Rico (1967-1992)

</div>

(a) 1967

(b) 1972

(a) 1977

(b) 1982

(c) 1987

(d) 1992

Source: Authors' elaboration.