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Data analysis applied to the evolution of the dependence on intergovernmental transfers: A case study in Colombia

Análisis de datos aplicados a la evolución de la dependencia de las transferencias intergubernamentales: Un estudio de caso en Colombia

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Resumen

La mayoría de las democracias modernas han descentralizado administrativamente gran parte de sus funciones, otorgando autonomía a los territorios municipales para gestionar la recaudación y el gasto de los ingresos tributarios. Sin embargo, otro tipo de ingresos a nivel local son transferidos desde el gobierno central con una asignación específica, frente a la cual los municipios no tienen autonomía en el gasto. Estas transferencias condicionadas o específicas de cada país representan en muchos casos la parte más importante del ingreso. Por lo tanto, se quiere determinar si los niveles de dependencia de las transferencias se deben a decisiones de administración o, por el contrario, responden a características regionales comunes, implementando un índice para medir la dependencia de las transferencias condicionadas de la nación a los municipios, tomando como Estudio de caso de estas entidades territoriales en un departamento de Colombia. Se recopilaron datos sobre el ingreso total y las transferencias nacionales de los municipios para los períodos fiscales entre 2008 y 2020. Para analizar mejor la dependencia de dichas transferencias en los municipios durante este período, se aplicó el algoritmo de clasificación k-medias, el cual encontró que los municipios se pueden agrupar en tres conglomerados. En primer lugar, se encontró que la mayoría de los municipios tienen una alta dependencia de las transferencias del país. Asimismo, se identificaron clusters regionales, en los que las zonas históricamente afectadas por el conflicto armado y la siembra de cultivos ilícitos presentaron mayor dependencia.

Palabras clave: transferencias nacionales condicionadas, gasto público, renta, relaciones intergubernamentales, k-means, impuestos.

Abstract

Most modern democracies have administratively decentralized a large part of their functions, granting municipal territories autonomy to manage the collection and expenditure of tax revenues. However, another type of income at the local level is transferred from the central government with a specific allocation, compared to which the municipalities have no autonomy in spending. These conditional or nation-specific transfers in many cases represent the most significant part of the income. Therefore, we want to determine whether the levels of dependence on transfers are due to administration decisions or, on the contrary, respond to common regional characteristics, implementing an index to measure the dependence on conditional transfers from the nation to the municipalities, taking as a study of case these territorial entities in a department of Colombia. Data on the total income and national transfers of the municipalities were collected for the fiscal periods between 2008 and 2020. To better analyze the dependence on such transfers in the municipalities during this period, the k-means classification algorithm was applied, the which found that the municipalities can be grouped into three conglomerates. Firstly, it was found that most municipalities have a high dependence on transfers from the nation. Likewise, regional clusters were identified, in which the areas historically affected by the armed conflict and the planting of illicit crops presented the greatest dependence.

Keywords: conditional national transfers, government spending, income, intergovernmental relations, k-means, taxes.

Introduction

Modern world states were consolidated as we know them to a large extent in the 20th century, with the universalization of democratic models. Those models led to the decentralization of part of the power and the administration of resources and responsibilities of central government units (in many cases authoritarian) to local government units. (Aghón, 1993; Ariza, S. D., y Chavarro, 2019; Rémy Prud'Homme, 1995; Rondinelli & Nellis, 1986; S. et al., 2020) conceptualize decentralization as the allocation of resources, functions, and responsibilities from the central government to local governments, that allow them to plan, manage and collect in the territory. Concerning the traditional model of austere and centralized taxation, (Hernández Vidal, 2019) indicates that this approach is oriented to the fulfillment of the financial obligations acquired by the State with the institutions that allow public credit, which affects the fiscal dependency on the municipalities and their capacity to make social spending.

Since the beginning of the second half of the 20th century, authors such as (Musgrave & Peacock, 1958; Oates, 1972; Stigler, 1957) discussed the need to distribute the provision of public goods based on the capacities and advantages that each instance of government within a State could have. They considered, for example, that national defense or international relations are public goods that must be provided at the central level, while municipal transport or aqueducts can be managed locally. (Ángeles Castro et al., 2019), in the theory of public finances, points out three main functions of governments, as follows: first, macroeconomic stabilization and economic growth, followed by the distribution of income through the national budget, with these first two functions in the central government, while the provision of public goods and services mainly falls to local governments.

The experts of decentralization have different positions regarding this topic. (Baskaran et al., 2016) present the contrasts between the literature trends that point to strengthening the provision of public services, innovation to perform reforms, and trends that argue that decentralization fosters corruption and government inefficiency. (Aldasoro & Seiferling, 2014) conclude that although decentralization yields benefits, it also leads to deterioration

in fiscal performance due to the increase in public spending that is insufficient to be financed with own resources. (Slavinskaite et al., 2020) hypothesize the benefits of the model as follows: goods and services provided locally are more efficient and appropriate due to the mobility of citizens, the political power of the vote, and the competition between local governments. In this regard, the democratic participation of citizens is significant since their empowerment allows public spending to be directed towards satisfying the necessary public goods and services with more efficient management of resources. (Digdowiseiso et al., 2020) and (Siburian, 2020) agree on the latter, indicating that there is a solid, positive, and significant relationship between fiscal decentralization and vertical inequality when democracy is considered as another system variable.

As a result of the decentralization process and the consequent powers and responsibilities assumed by local governments, the latter afford more expenses, resulting in a vertical fiscal imbalance, that is, an increase in the gap between the income and expenses of subnational governments (Bird & Tarasov, 2004). This fiscal gap can be financed with the payment of transfers from the central government, thus achieving a positive effect on fiscal sustainability and reducing the vertical fiscal imbalance (Li & Du, 2021).

(Boadway & Shah, 2007) and (Cordero et al., 2022) state that together with their income from local taxes, unrestricted transfers have become an important element for financing current expenses in local administrations. Therefore, in addition to the principle of sufficiency, transfers also reduce inequality, allowing the fiscal capacities of distinct subnational entities not to produce substantial differences in the provision of public goods and services for similar fiscal efforts (Leon-Cazares et al., 2021).

Nevertheless, different authors agree that transfers from central to local government agencies create financial dependency on the latter. (González Ramírez & Gomez Galarza, 2020) point out that Mexican municipal governments predominantly depend on Federal Government resources, implying a fiscal autonomy loss in the municipalities. (Herrera-Díaz, L., González-Acolt, R., & Alcantar-López, 2021) propose that, in the Mexican municipalities case, transfers are an incentive to go into debt thanks to the

increase in federal resources received, boosting the debt per capita by 86.49 Mexican pesos for each additional $1,000 of transfers per inhabitant. On the other hand, in the Colombian case, (CEPAL, 2022) indicate that transfers represent 60% of municipal income.

(Taiwo, 2022) finds that Nigerian local government units rely mainly on federal government transfers, in which a 1% increase in transfers leads to a 0.65% reduction in own revenue. In Tanzania, (Masaki, 2018) argues that, in many cases, municipal authorities are ineffective in collecting local taxes due to the fragility of institutional resources and the political costs of enforcing taxes, which motivates the dependence on intergovernmental transfers. In contrast, (Panao, 2021) presents two scenarios occurring in the Philippines: the first group of subnational entities where dependence on income transferred from the central government is high, nullifying the principle of fiscal autonomy. Also, a second group with less dependence on transfers is more active in generating its resources. This latter group also tends to allocate more resources to public welfare.

The European Union countries and some post-Soviet countries in Eastern Europe are not strange to this reality, considering that the expenses financed with resources from the federal level are higher than the decentralized income. In this sense, (Pasichnyi et al., 2019) state that income decentralization has negatively affected economic growth. In the specific case of the regions in Romania, (Gavriluţă et al., 2020) indicate that state budget transfers have done very little in reducing inequality and poverty in general.

From the perspective of reducing inequality in local governments, (Madrigal Delgado & Bueno Cevada, 2019) point out that transfers produced unwanted effects on municipal public finances. Furthermore, they considered that by prioritizing the most marginalized municipalities for the distribution of resources, many of the larger or least marginalized municipalities compensate for the relative decrease in these resources through debt and not through adequate management of local taxes that the decentralized model has granted them. (Beramendi & Rogers, 2020) indicate that after the great recession, there has been greater interpersonal inequality and a lower interregional inequality in 21

countries of the Organization for Economic Cooperation and Development (OECD). In contrast, (Mendoza-Velázquez et al., 2022) state that federal transfers positively affect local economic growth. Also, (Kim et al., 2020) propose that fiscal decentralization has a statistically significant impact on inclusive growth, demonstrated in redistribution indicators such as the level of the Gini coefficient and the labor share of income.

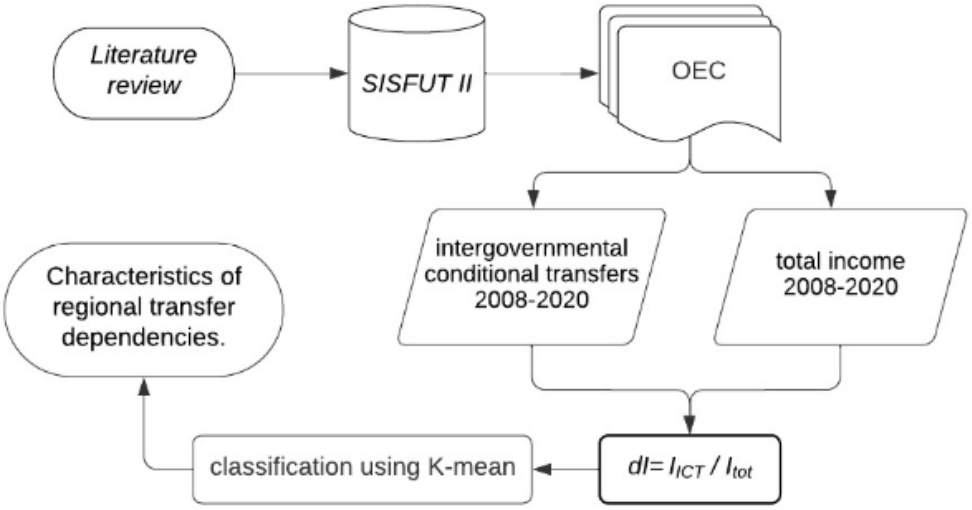
In the Colombian case, transfers are regulated in the General Participation System and have become the primary source of financing for Colombian municipalities, mainly due to the fiscal efforts made. It can be found, for example, that the tax revenues of the sixth category municipalities, on average, only represent 12.07% of the income. Likewise, social and physical infrastructure investment has been financed by 88.51% with transfer resources in the first two decades of the 21st century, so the self-financing of investment is only around 11.49% (Delgado Ruiz et al., 2020). For the 2016-2020 period, it is evident that the dependence on national transfers is not consistent, where the large cities are financed mainly with their own resources. On the other hand, agglomerated cities have resources and receive transfers similarly. In contrast, for emerging and intermediate cities and rural municipalities, municipal income depends on transfers between 65% and 70% (Ministerio de Vivienda, 2021).

This study aims to determine the levels of dependency on intergovernmental conditional transfers for the 40 municipalities of the Norte de Santander state in Colombia. Concerning one of them, (Sánchez-Becerra & Rodríguez, 2020) point out that Ocaña, the second municipality by population in the department, presents relatively low levels of growth in its income compared to other socioeconomically similar ones in the country in the period 2009-2017. By context, this state is located in northeastern Colombia in the border area with Venezuela. It has 1,651,278 inhabitants, of which 1,311,761 are in municipal capitals and 339,517 in scattered populated or rural centers.

Materials and Methods

The development of this study has taken into account the procedure described in Figure 1, starting with the introduction which was prepared from the review of literature in databases such as Scopus and Scielo on aspects related to fiscal decentralization, intergovernmental relations and intergovernmental transfers.

Figure 1: Materials and methods



In relation to the object of the study, the National Planning Department of Colombia has the SISFUT II, Information System of the Territorial Single Form, which is a repository of information of the reports of the territorial entities to the Consolidator of Finance and Public Information CHIP. The data used to develop the study was taken from this repository and is described below.

Data description

The data used in this study was taken from the SISFUT II. In this database you have access to the budget executions of the country's departments and municipalities through the file "OEC 2000-2020 Departments and Municipalities".

A sample from 2008 to 2020 was taken from this dataset, containing the total annual income of the 40 municipalities of the Norte de Santander State in Colombia. In addition, the intergovernmental conditional transfers (ICT), also called national specific or conditional grants, were extracted for the same period (Figure I). The city with the highest total income from 2008 to 2020 is Cúcuta, the Capital and most significant city, which accounts for 53.8% of the total income of all municipalities in the state. It is followed by Villa del Rosario and Ocaña, which received 4.96 and 4.87%, respectively. Similarly, Cúcuta acquired the highest ICT in that same period, accounting for 56.2% of all ICT in the state, again followed by Villa del Rosario and Ocaña, granted 5.20 and 4.80%, respectively. Table 1 presents the total income in COP and ICT for the municipalities in Norte de Santander, with the highest total income from 2008 to 2020. It is worth noting that the other 25 municipalities not presented in Table 1 received less than 1% of the state's total income and ICT during the studied period.

Table 1**:** Total income in COP (Colombian pesos) and intergovernmental conditional transfers (ICT) for the municipalities in Norte de Santander with the highest total income from 2008 to 2020.

Municipality	Total income				Intergovernmental conditional transfers			
	2008	2012	2016	2020	2008	2012	2016	2020
Cúcuta	347,249	519,235	826,618	1,200,000	251,916	344,301	563,569	879,447
Villa del Rosario	21,097	39,764	81,052	130,674	16,119	30,675	51,282	98,763
Ocaña	25,441	44,432	65,114	106,131	18,101	30,657	44,499	79,991
Los Patios	14,754	32,342	65,954	83,332	8,836	15,774	25,291	46,363
Tibú	22,582	25,111	44,218	65,343	9,895	14,708	24,675	42,095
Pamplona	15,588	19,540	33,875	42,797	8,673	12,793	21,471	30,317
Abrego	10,104	18,271	28,109	35,239	8,868	15,691	20,519	29,894
El Zulia	9,554	12,603	28,695	30,493	6,583	9,320	18,934	22,537
Sardinata	9,461	13,784	17,276	30,725	6,984	11,862	13,110	24,291
Toledo	7,714	10,374	23,166	31,298	4,989	7,595	11,890	17,544
Teorama	7,911	11,767	22,303	23,993	6,531	8,726	12,770	18,088
El Tarra	7,097	10,086	14,557	26,011	5,308	7,700	10,733	19,590
Convención	7,796	11,417	17,768	29,144	6,057	9,741	13,749	20,047
El Carmen	7,855	11,714	15,470	22,708	6,162	8,956	12,151	16,325
San Calixto	5,004	9,648	13,095	21,327	4,153	7,419	9,664	13,226

Source: Own elaboration, with data extracted from SISFUT II, 2022.

The considerable disparity in total income and intergovernmental transfers in the municipalities makes it challenging to compare their situation. For that reason, an indicator was developed with those variables to estimate the dependence of municipal revenues on ICT as follows:

$$\mathrm{dI} = \frac{\mathrm{I}_{ICT}}{\mathrm{I}_{\mathrm{tot}}} \qquad \textit{Eq. 1}$$

Where dI is the dependence index, I_{ICT} is the intergovernmental conditional transfer income, and $\mathrm{I}_{\mathrm{tot}}$ the total income of each municipality.

Intergovernmental transfers dependence analysis using k-means clustering

The k-means algorithm is an unsupervised learning method for classification in which k represents the number of groups or clusters. In a cluster, all elements have similar features and different from the elements of another cluster. This work used k-means to classify the state's municipalities according to the distribution of dependencies of the nation's transfers in 2008-2020.

The algorithm starts by defining k random centroids and then calculating the distance from each data point to the centroids to locate them at the nearest centroid. To measure the distance between points, the Euclidean distance is used. Then, new centroids for each cluster are calculated, and the process is repeated until the number of iterations is reached, or the cluster assignments stop changing. The standard algorithm for k-means is the Hartigan-Wong algorithm, which intends to minimize the total within-cluster variation (WCV) expressed in Eq 2.

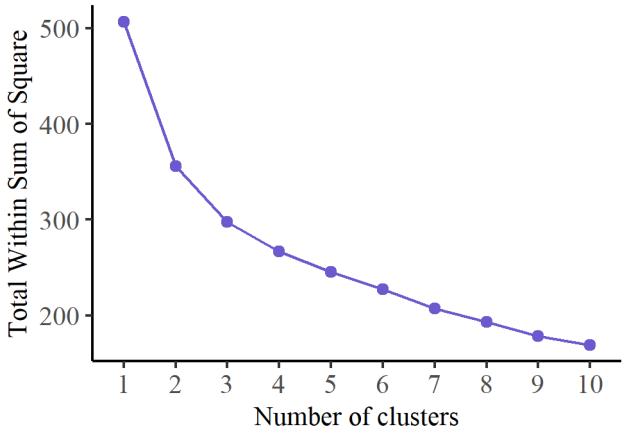
$$WCV = \sum_{k=1}^{k} \sum_{x_i \in C_k} (x_i - \mu_k)^2 \qquad \textit{Eq. 2}$$

Where C_k refers to the cluster k, x_i is a data point in C_k, and μ_k is the mean value of all data points assigned to C_k. The number of clusters k significantly influences the result of the classification. Mainly due to the importance of the sum of the squared errors (SSE) in WCV. Therefore, two methods are used to determine the optimal number of clusters: the elbow method and the silhouette method.

Result and discussion

The analysis of the total income and ICT in the 40 central municipalities of Norte de Santander, Colombia, revealed significant differences. Therefore, cluster analysis was applied to explore the data and find trends in the dependence of municipal revenues on ICT. First, the transference index was calculated for the 40 municipalities from 2008 to 2020. Then, that data served as input for the cluster analysis. The data were classified into three clusters, as it is a number that minimizes the total within-cluster variation (Figure2).

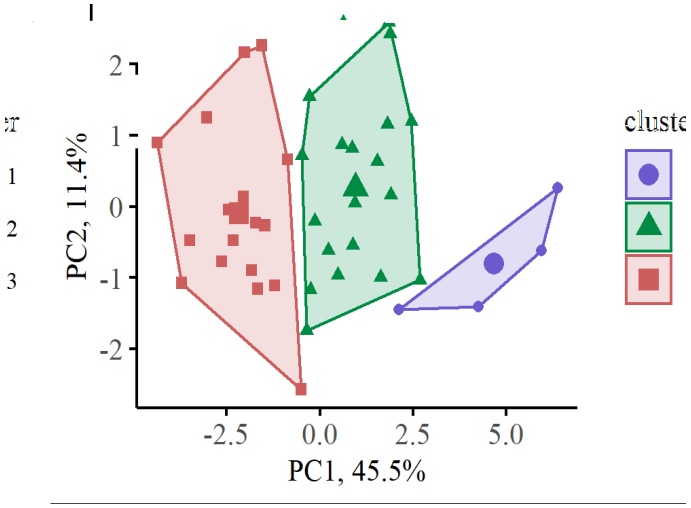
Figure 2: Optimum number of clusters according to the elbow method.



Source: Own elaboration

Figure 2 shows the cluster's two-dimensional graphic representation as a function of the principal components PC1 and PC2, which account for almost 60% of the dataset variance. From this plot, we discard the presence of outliers. C1, C2, and C3 refer to clusters 1, 2, and 3 and contain 4, 19, and 17 municipalities, respectively.

Figure 3: Graphical representation of clusters as a function of principal components PC1 and PC2.



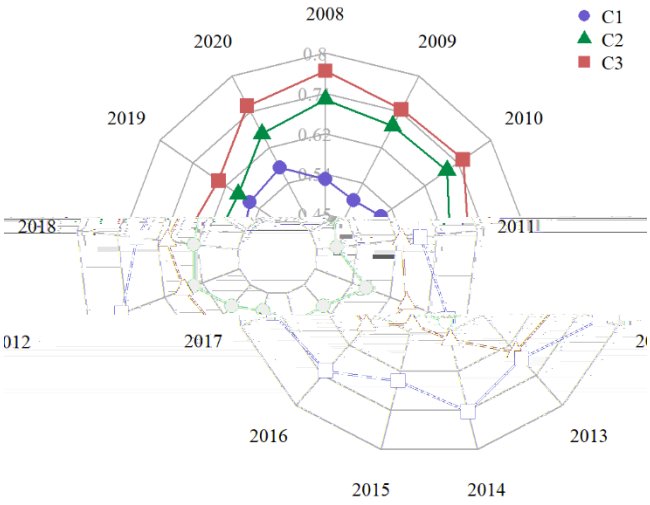
Source: Own elaboration

These clusters make it possible to classify the degree of dependency in the municipalities of Norte de Santander on the nation's transfers into low (C1), medium (C2), and high (C3) categories. The average dependency for each category was 0.528, 0.622, and 0.703, respectively. Most municipalities are between medium and high levels, placing only four territorial entities in low levels of dependency.

Figure III presents the variation of the indicator through the evaluation time, where the municipalities belonging to C1 show a considerable decrease between 2008 and 2011. This contrasts with the significant increase that occurs in the municipalities of C1. C2 and C3. A downward trend in the dependency index was observed in all three clusters during the 2018 and 2019 fiscal years. However, that trend changed in 2020 due to the COVID-19 pandemic. Isolation measures, the closure of SMEs (small and medium-sized enterprises), and the consequent contraction of the economy caused the nation's dependence on transfers to increase in all municipal categories.

The dependency data shows another peculiarity in the start and end periods of the municipal administrations: 2008-2011, 2012-2015, and 2016-2019. In each of these periods, there is a high dependency on the nation's transfers in the first year of government and minimal dependency points in the last year. In addition, 2012 presented the highest value of the transference index in each cluster.

Figure 4: Radar plot of the dependence index for each cluster in the 2008-2020 period.

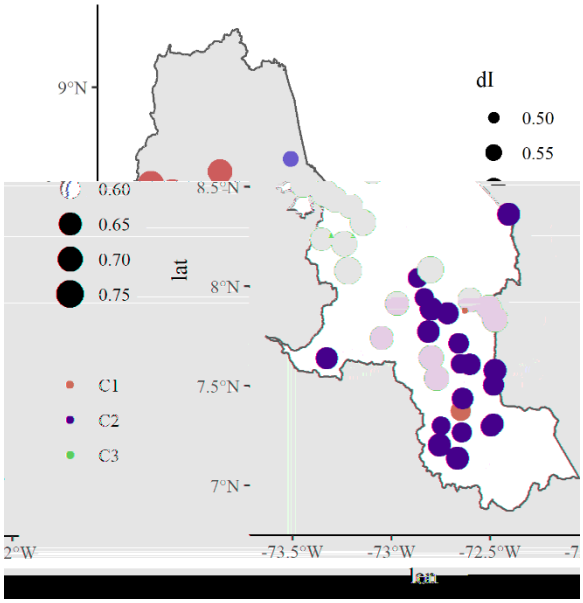


Source: Own elaboration

Figure IV shows the map of Norte de Santander and the forty municipalities classified in the three clusters found. Municipalities of the same cluster seem to be close in location. The northern part of the department is known as the Catatumbo region. Most of it contains municipalities belonging to cluster 3, with the most significant dependence on ICT, except for Tibú, which is of low dependence. In contrast, the municipalities that make up the department's southeast are primarily of medium dependency (C2). However, it also contains three municipalities of low dependency (C1) and a few of high dependency (C3). The municipalities in the border zone with Venezuela (east) and the Colombian state of Santander (west) present less dependency than the municipalities located in the Catatumbo zone, which has historically been a region affected by the armed conflict and the planting of illicit crops, preventing the strengthening of democracy and administrative entities in the territory.

Figure 5: Norte de Santander map with the 40 municipalities and their classification

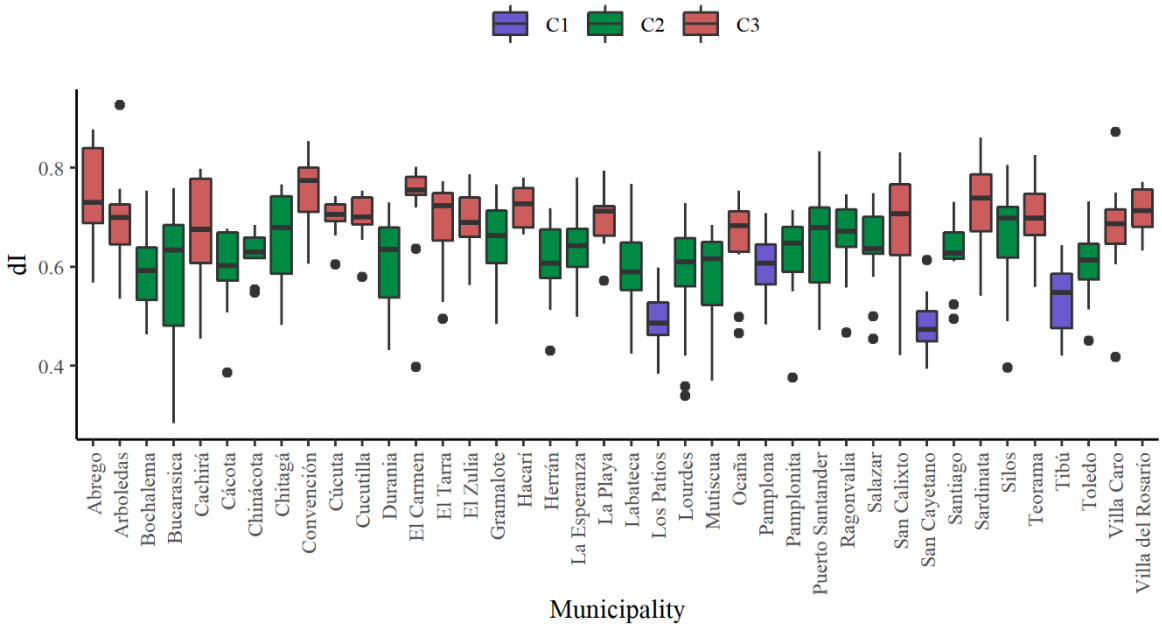
D F F R U G L Q J W R W K H G H S H Q G H Q F H R Q L Q W H U J R Y H U Q P H Q W D



Source: Own elaboration

Additionally, it was found that municipalities with a low dependency index (C1) tend to be more stable in their variance throughout the periods analyzed (standard deviation of 0.06 on average). While municipalities with higher dependencies, such as those in C2 and C3, had more variance in their data each year. Like Bucarasica (C2), which went from a dependency index of 0.71 to 0.28 in 2011. Moreover, San Calixto (C3 and Catatumbo region) decreased its dependency index from 0.71 to 0.42 in 2019. Figure V shows that the municipalities in C3 do not present a normal distribution. The high variance in the data indicates an unstable behavior in the analyzed period for a large part of the data. Ocaña was classified as a municipality with the highest dependency, even after two years (2011 and 2013) of low dependency, unlike Ábrego, where dependency was high throughout the study period. This study's observations with low dependence on the nation's transfers were not considered outliers due to the high number of standard deviations outside the upper and lower extremes of the whisker box.

Figure VI Boxplot of the nation's transfers dependence of the Norte de Santander municipalities during the 2008-2020 period.



Source: Own elaboration

Conclusion

This study proposed an indicator to analyze the dependence on the nation's transfers of local governments. The indicator considers these transfers and the total income of different municipalities and cities. The historical values of this indicator in forty municipalities of Norte de Santander, Colombia, were studied from 2008 to 2020. Cluster analysis was used in the dataset to analyze the municipalities' economic behavior in greater depth. It was found that the municipalities of Norte de Santander mainly depend on transfers from the nation, where 19 are in medium dependence and 17 in high. Likewise, it is evident in the different clusters that during the fiscal years where there is a change of municipal government, the dependence on transfers increases and then decreases, reaching minimum levels in the last year of the local government.

Likewise, geographically regional behaviors were detected, with the municipalities that constitute the Catatumbo region concentrating most of the municipalities with a high dependency on transfers. The above may be due to the weakness of state institutions caused by the armed conflict that these municipalities have historically experienced, the

presence of illicit crops, and the relationship of the regional economy with these activities. While the border municipalities and the southeastern area of the department show indicators of less dependency.

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