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# European Regional Policy

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European Regional Policy

# How integrated regional financial markets are in Europe? A first gauge based on active securitised loans

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## Abstract:

Little is known about the degree of integration of financial markets at subnational level in the EU. This article provides new evidence on interregional loan flows within Europe. Building on the "Loan Level Initiative" launched by the ECB, with more than 35 million active loans, we built a georeferenced dataset of securitised loans, covering the period 2014-2018 and the 166 European NUTS 2 regions for which data exists. After reviewing the complex nature of the dataset, we explored its geographical dimension, and conduct an econometric analysis focused on explaining the regional demand for such loans, using different explanatory variables related to the geographic and the socio-economic features of the regions, and alternative panel data specifications (classic versus spatial econometric ones).

**Keywords:** Capital flows; loans; securitized loans; European financial integration.
**JEL Classification:** O33; O34; J16.

## ¿Cuán integrados están los mercados financieros regionales en Europa? Un primer indicador basado en préstamos titulizados activos

## Resumen:

Poco se sabe sobre el grado de integración de los mercados financieros a nivel regional en la UE. Este artículo proporciona un primer vistazo a los flujos de préstamos interregionales dentro de Europa. Partiendo de la base de datos «Loan Level Initiative» lanzada por el BCE, que permite acceder a información de más de 35 millones de préstamos activos, construimos un conjunto de datos georreferenciados de préstamos titulizados, capaz de cubrir el periodo 2014-2018 y las 166 regiones europeas NUTS 2 para las que dichos datos existen. Tras depurar y explorar el conjunto de datos, en este artículo exploramos su dimensión geográfica, mediante un análisis gráfico y econométrico centrados en explicar la demanda regional de dichos préstamos, utilizando variables geográficas y socio-económicas, y empleando diferentes especificaciones de datos de panel, clásicos y con elementos de econometría espacial.

**Palabras clave:** Flujos de capital; préstamos; préstamos titulizados; integración financiera europea.
**Clasificación JEL:** O33; O34; J16.

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## 1. Introduction

The aim of this paper is to provide new evidence about the subnational financial integration in Europe, by exploring the "Loan Level Initiative", a new dataset containing more than 35 million active securitized loans. Covering the period 2014-2018 and 166 European NUTS 2 regions, we analyse the regional demand for such loans, using different panel data models and explanatory variables related to the geographic and the socio-economic features of the regions.

Capital mobility, and integrated capital markets facilitate risk sharing across sectors and countries, helping to cushion economic shocks on consumption and investment. In line with (Baele, et al., 2004), it can be said that financial markets are integrated when different agents, irrespective of their place of residence, share a common set of rules, are treated equally, and have equal access to the existing set of financial instruments. Despite the progress made in removing the obstacles to capital mobility in Europe, there is evidence about a high degree of home bias in capital flows, as has been commented by several authors (Feldstein & Horioka, 1980; Valiante, 2016). While the cross-border integration of European capital markets has increased in recent years, risk sharing remains below the values observed in the United States (European Commission, 2015). This home bias is a key puzzle in open macroeconomics, but not restricted only to capital flows as it is also found in other flows like migration, trade of goods or services.

French & Poterba (1991) were the first to document a lack of diversification in equity investing highlighting a domestic bias in share's owners across countries.(Lewis, 1999) goes one step further concluding that individuals underperform hedging risks across countries. More recently (Dahlquist & Robertsson, 2001) show how foreign investors tend to penalize firms with low market liquidity, with little presence in international markets and with a dominant owner, typically small and medium enterprises, pointing to an institutional investor bias, as foreign investors typically are mutual funds or other institutional investors. Although this home bias is well documented, this literature focuses mainly on cross-country analysis. Spatial disaggregation at the sub-national level remains off the research radar due to data scarcity.

The available information on the interconnectedness of financial institutions and between them and the rest of the agents within the EU is far from optimal. Some previous work has attempted to explore financial integration between markets using asset return data, which are readily available even daily. For example, in (Worthington & Higgs, 2010) stock market indices for 11 European countries are analysed using Granger causality tests and VAR procedures to examine causal relationships among these markets.

To the best of our knowledge, there is no complete and homogeneous source for tracking region-to-region (R2R) credit flows within or between countries in the EU, with the ability to link the sub-national units such as regions (NUTS 2), provinces (NUTS 3) or cities (NUTS 5). Within countries, no information is available regarding the region where the economic agents taking/issuing the credit/debit are located. For cross-border flows related to loans, although very good data are available at the country level, it is difficult to disaggregate such flows at the sub-national level.

As commented, the aim of this article is to shed light into the financial relations in Europe, offering new evidence about the interregional flows of loans. Of course, we do not expect to obtain a full detailed and accurate picture of the complex financial interrelations in the EU. More humbly, the intention is to explore a new dataset (ECB-EDW), the “Loan-level Initiative” recently launched by the European Central Bank (ECB) and explore the geographical dimension of such immense and innovative dataset, and to evaluate to what extent it can (partially) fill the gap about the interregional financial integration in Europe.

New instruments in the financial market became more important in the cycle of finance-investment and savings-financing, and financial innovation like securitization has played a key role in increasing the variety and complexity of available assets allowing investors to diversify their funds and hedge more efficiently.

The loan-level initiative establishes specific loan-by-loan information requirements both for asset-backed securities (ABSs) and for non-marketable debt instruments backed by eligible credit claims accepted as collateral in Euro system credit operations. The aim of that initiative is to add transparency to the financial sector in Europe after the big crisis in 2008. It includes different types of loans: residential mortgage-backed securities (RMBSs), ABSs backed by small and medium-sized enterprise (SME) loans, consumer ABSs, auto loan ABSs and leasing ABSs, ABSs backed by credit card receivables, etc.

The exploration and data provision of this innovative dataset is conducted by the European Datawarehouse and the ECB[1]. The dataset is currently being used with the BigNOMICS Project[2], and initiative developed by the JRC-Ispra (Italy), where they have analysed the regional dimension of the mortgage loans with the objective of analysing the local drivers of loan-mortgages defaults in seven EU countries.

In principle, this new data source could potentially provide useful insights for tracking the interregional flows of short-term capital movements, both within and between EU28 countries and to explore if these financial instruments have had a positive effect on the volume of interregional/international financial interrelationship. However, as indicated in the next section, the current layout of the dataset faces some limitations in the proper identification of the territorial origin of the capital flow (the region emitting the loan), as well as in terms of the overall representativeness of the true levels of loans in Europe. In any case, the information related to the destination side of the flows is extremely rich, allowing for analyse the financial exposure of some regions to a variety of different assets.

This is precisely the intention of our econometric analysis, able to open the black box of the regional demand of (securitized) loans for different European countries at the same time. This is conducted by means of different panel data specifications, where the regional demand for loans is modelled against different explanatory variables related to the geo-graphic and the socio-economic features of the region. Such analysis encompasses standard panel data specifications as well as spatial econometric ones, taking the form of a spatial error panel model with fixed effects (Elhorst, 2003).

The rest of the article have the following structure: in the second section, we revise the state of the art with respect to the knowledge of the financial linkages at the country and sub-national level. Then, we describe the dataset and the methodology used. Next, we analyse the results obtained, first developing a descriptive analysis, and then by a panel data econometric analysis, with the aim of exploring the geographical dimensions of the data obtained. The paper finish with a concluding sector defining potential extensions of this original first incursion in this complex and relevant topic.

## 2. Background

### 2.1. Financial integration in Europe

The degree to which an economy's financial system is developed determines the level of development and well-being of its members. For the development of business activities and for households' access to durable consumer goods and adequate housing, the availability of financial resources at acceptable cost, maturity and volume conditions is fundamental.

In advanced economies, the degree of development of their financial system can be observed both in the number and volume of financial agents and assets available to non-financial agents (savers and investors) and in the depth of financial linkages (between firms, households, and financial intermediaries) and the degree of development of their financial markets. Financial intermediation involves not only the simple transfer of resources from one agent to another, but also the transfer of risk (Obstfeld, 1994). Thus, in developed financial systems, the greater availability of different asset types allows agents for transfer risk, and investors for diversifying risk in a more efficient manner. In this process of transferring risk from some agents to others, the securitization of loans, both with and without collateral, has been an instrument that

[1] https://ec.europa.eu/jrc/communities/en/community/big-data-and-forecasting-economic-developments
[2] https://www.ecb.europa.eu/stats/financial_corporations/list_of_financial_institutions/html/index.en.html

had experienced a wide expansion in recent years, and that has become most notorious, maybe with negative connotations, due to the subprime crisis.

With increasingly more open economies and the substitution of restrictions on international capital transactions by a common, and clear, set of norms regulating financial flows lead to developed financial systems that are also characterized by deeper financial interrelations with non-resident agents. Although their positive, and controversial, potential effect on economic growth, capital mobility also has some associated risks (Arif-Ur-Rahman & Inaba, 2020; Bonfiglioli, 2008; Feldstein & Horioka, 1980).

Easing capital mobility increase financial integration between markets in different countries, who become increasingly financially interconnected. The process of financial integration results in a convergence of prices and returns (Valiante, 2016) and intensified cross-border financial activity (Bonfiglioli, 2008). Price convergence and intense cross border flows is reached when similar market participants face a common set of rules, have equal access to the set of financial instruments and are treated equally when they are active in the market regardless of their region of origin (Baele, et al., 2004). From a geographical point of view, the existence of financial flows between agents located in different regions within and between countries is a consequence of the openness and integration of the financial systems of different countries. With the suppression of all kinds of administrative and transaction costs (information, transformation, currency conversion, formal reporting obligations, etc.), as well as the perception of risk differentials depending on the location of the investor and the debtor, the intensity of these flows is expected to increase, as well as the convergence in prices and returns in instruments that are available to all resident in the integrated area.

Deep financial linkages between agents throughout the economy should be catalysed by a common regulatory framework, a single supervisor, a single currency (as in the European Monetary Union), a single payment system, the freedom to open subsidiaries and invest in financial institutions, and a single tax system. As in (Hobza & Zeugner, 2014) is pointed, the strength of financial linkages among euro area countries increased significantly in the pre-crisis period, leading to the emergence of a "euro bias" in cross-border holdings of various financial assets. The authors cite the role of German banks in financing the Spanish construction sector as an example of this "euro bias".

Just as the exchange of goods and services in the EU has intensified, facilitated by a common regulatory framework, bilateral financial flows have also increased, and to some extent the two factors are interrelated. For example, it is generally accepted that the surplus countries, which also act as intermediaries for flows from the rest of the world, have financed the current account deficits and investment surpluses in the euro area periphery (Hobza & Zeugner, 2014; Waysand, et al., 2010).

In any case, although equity, bond and interbank markets in Europe appear to be highly integrated, there is still a long way to go to achieve a truly unique financial system. As (Dahlquist & Robertsson, 2001) suggests, a clear institutional investor bias exists. Interbank and credit markets in Europe became more fragmented after the 2008 crisis (Mayordomo, et al., 2015). This is especially true in peripheral countries, where financing costs are higher, even after the ECB's Securities Market Program (SMP) and Long-Term Refinancing Operation (LTRO). It is not only the interbank market that is fragmented. Corporate transactions are also affected by a country bias. As pointed by (Umber, et al., 2014), for mergers and acquisitions in Europe, national borders seem to be a strong barrier.

Some attempts to shed light on this "black box" are reported in Table 1 which presents a selection of papers. In all of them, problems of data limitations have been reported, with reference to the lack of consistency in the reported value of transactions between debtors and creditors, the absence of data for some transactions, the lack of information for non-reporting countries, etc. Our analysis is not an exception, as we will explain in the following section.

**Table 1.**
**Estimation of financial interrelationships in Europe. Previous experiences**

| Work | Countries | Time span |
|---|---|---|
| (Hobza & Zeugner, 2014) Gross financial flows (portfolio investment, other investment, FDI and reserve assets.) | Germany, Greece, Spain, France, Italy, Austria, Portugal, Benelux, Rest of EA, Poland, Sweden, UK, Rest of EU, and Non-EU (detailed for Switzerland) | average 2004- 2006<br>average 2007- 2009<br>average 2010-2012 |
| (Waysand, et al., 2010) Bilateral external financial asset and liabilities, excluding reserve assets and derivatives. | Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom | 2001-2008 |
| (Kubeleca & Sa, 2012) Bilateral external assets and liabilities (foreign direct investment, portfolio equity, debt, and reserves) | Germany, Spain, France, Italy, Portugal, UK, Rest | 1980-2005 |

## 2.2. Securitized loans

According to (Pinto & Alves, 2016), the first European securitization transaction was a RMBS, issued in the UK in 1987. Soon, other countries such as Spain and France begin to issue ABS, in the early 1990s, followed by Finland, Sweden, Ireland, Italy, and Germany, in the mid-1990s. From the late 1990s, securitization really began to take off, supported by legislative changes in many countries. The introduction of the Euro in 1999 increased the importance of the European securitization market, who is, in fact, a collection of distinct markets. Securitization was hit by the subprime crises in the 2007-2009 period, but since 2010 the number of asset securitization bonds is around 80 per year. This historical development of the securitization market helps to understand the peculiarities in the disaggregation of the data at a country level.

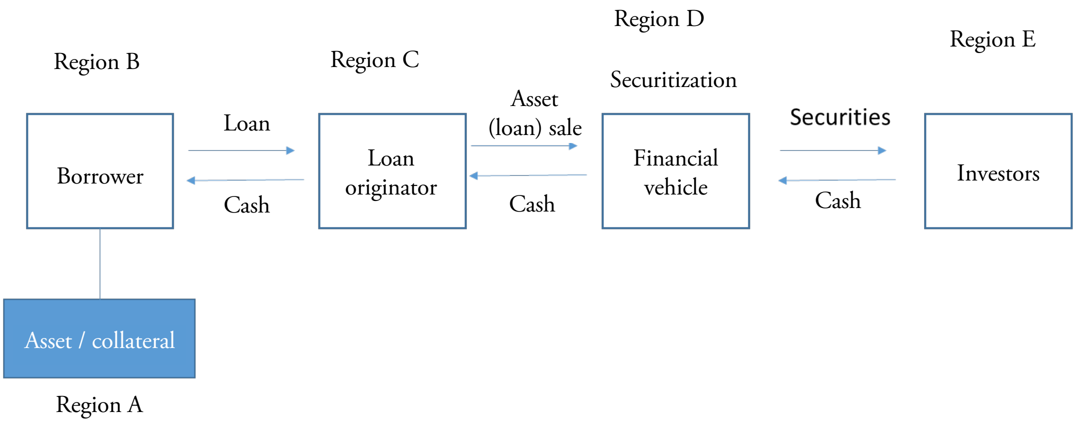
Banks' liquidity needs and risk diversification are the theoretical determinants of securitization (Farruggio & Uhde, 2015). Therefore, the actual liquidity needs of banks and the cost of alternative funding sources, such as traditional retail deposits, should influence the securitization process. Loan activity is also expected to generate high securitization activity, so the main drivers of securitization should be the same as for loans (high activity in the housing market, increase in new car sales, consumer purchases, etc.).

In this line, (Bannier & Hänsel, 2008), with data from the period 1997-2004, shows that the issuance of collateralized loan obligations (CLOs) appears to be an appropriate funding tool for large banks with low liquidity and high risk, as securitization is also a risk transfer tool. In their study, these authors also find a significant "reverse" regulatory arbitrage effect: banks with low Tier 1 capital securitize significantly less than banks with high Tier 1 capital.

In this study, we analyse data in the EDW repository on securitized asset-backed loans. By securitization operation some income generating assets as loans are pooled and transformed into tradable securities. These securities are sold to institutional investors, financial intermediaries, or, highly unusual, directly to the public. This operation transforms illiquid assets into securities, that ideally have lower risks than the original illiquid asset (throughout diversification of individual risks or by insurance if the operation count with third-party credit enhancers), providing liquidity to the original lender. In addition, securitization also acts as a risk transfer mechanism, transferring credit risk from the lender to the financial vehicle and ultimately to the purchasers of the securitized loans, as the bursting of the housing bubble in 2007-08 taught us.

As mentioned above, securitized loans are mainly purchased by investment funds and institutional investors. In recent years, other agents such as the ECB have emerged as active buyers, but their role is marginal in the ABS market. The Asset Purchase Programs (APP) is part of the ECB's set of monetary policy instruments, and among other instruments, the ECB counts with the Asset-Backed Securities Purchase Program (ABSPP), under which the ECB purchases eligible asset-backed securities. Between November 21, 2014 and June 2022, the Eurosystem conducted net purchases of asset-backed securities under the APP, accumulating a value of 30,000 million euros in March 2020[3]. While significant in absolute terms, this represents only 1.2% of the total cumulative purchases of the APP, which essentially comprises Public Sector Purchase Program (PSPP) assets, and only 3% of the outstanding balance of active (outstanding) loans in the EDW database (the EDW database does not include all the ABS issued in the Euro Area).

**FIGURE 1.**
**The geographical dimension of securitized loans**




**Source:** Own elaboration.

Figure 1 provides a simple illustration of the financial flows involved in a typical securitization transaction. The spatial dimension of this process is also highlighted in this figure. In a securitization operation, it is possible to identify 4 types of agents and their spatial locations (which in some cases may be the same), together with the location of the collateral used in the original loan operation. These different locations are key determinants in identifying where financial flows originate and terminate in this study. From a purely financial point of view, in the securitization process we can identify a debtor (original borrower) located in region B and a creditor located in region E (final investors). The rest of the agents in the operation are intermediaries in the credit investment operation. Ideally, if region B and region E are known, as well as the value of the securitized assets, we will have a direct indicator of financial linkages at the regional level. Identifying and assessing this flow was the main objective of this exploratory analysis.

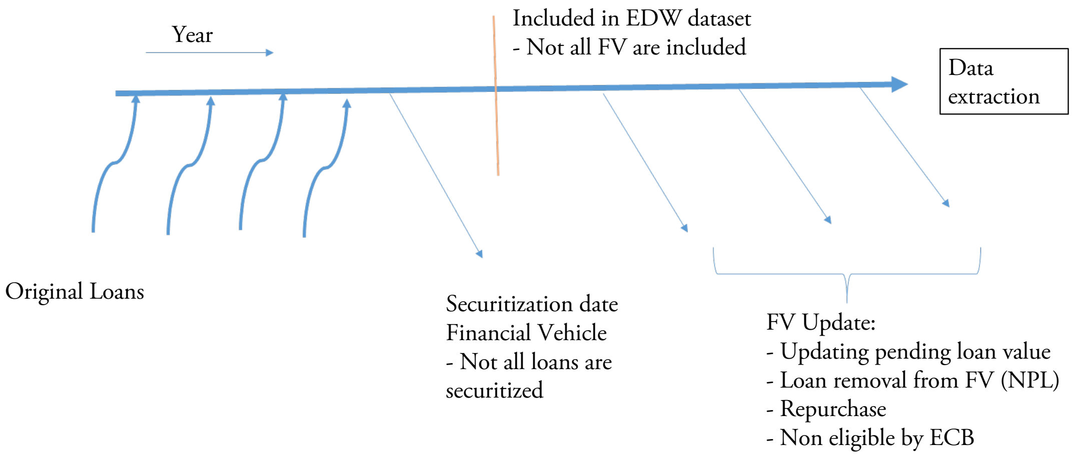
However, to put our feet on the ground and advance the results, the database used in this study (EDW) only allows us to identify the regions D (legal address of the financial vehicle) and B/A (region where the debtor is located or the place where the collateral is located). Although the database contains information on the originator of the loan, this information cannot be decoded due to the anonymization of the data. Therefore, in practice, the regions C and E in Figure 1 cannot be identified, which limits the potential use of this source for the original objective of the analysis, i.e., to truly follow the origin-destination financial flows (loans) in Europe.

It is also necessary to mention the temporal dimension of securitized loans. Several important dates must be kept in mind because of their impact on the valuation of the financial operations collected in the EDW database. Figure 2 summarizes the temporal scheme of a securitized loan and how the main milestones are recorded by the dataset before it is extracted and analysed, to facilitate the understanding of the

[3] See original data in the url https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html#abspp

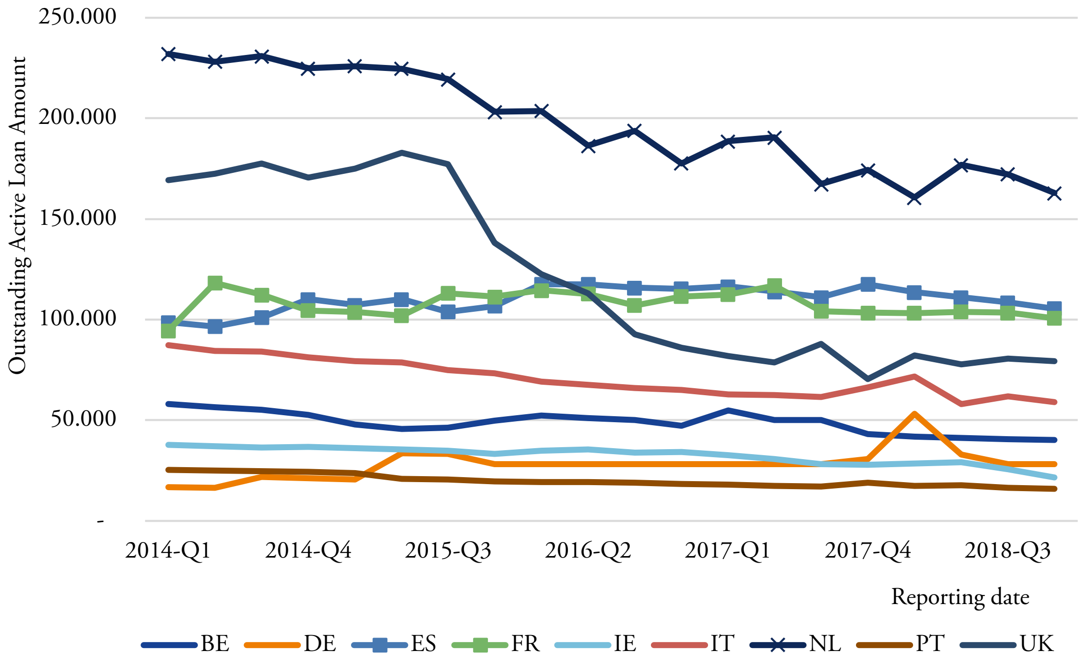
information contained in the dataset. The database contains the valuation of the outstanding debt on the loans contained in a financial vehicle at a given date after the date on which the financial vehicles were created. It is expected that the value of the outstanding debt will become smaller and smaller over time (see Figures A.1 and A.2 in the appendix), therefore, the value of the financial vehicle will decrease naturally over time. When the financial vehicle is created, loans that were previously issued are grouped together, so that the same financial vehicle may contain different generations of loans, issued at different dates. Thus, when the economy is in a credit expansion phase, it is expected that the number and volume of financial vehicles will be greater, which will naturally lose volume, as the underlying loans are cancelled or even lose their value due to default. In this article, we will consider the evolution of the amount of active loans in the EDW database as the indicator of the financial interrelationship among regions, and therefore, the value reported represent the value of pending debt in a given year irrespective of the origination date. As Figures 3 and 4 make clear, the consideration of one or the other approach is important in understanding the dynamics of the loan data collected in the database and their relationship to the credit dynamics observed in each country. For example, the reduction in the volume of outstanding collateralized mortgage loans located in Spain does not imply that lending in Spain is declining over time, but rather that the outstanding value of loans embedded in the financial vehicle is declining. As an example, the outstanding value of mortgage loans with collateral in Spain in 2006 still represents 3.5% of the outstanding value at the end of 2018 of all loans included in the financial vehicle. The expansion of mortgage lending in Spain and Ireland, linked to the housing bubble prior to 2008 is still discernible in the database, although the composition of the financial vehicle at the end of 2018 shows a high weight of loans with collateral in France granted from 2014 onwards.

**FIGURE 2.**
**Scheme summarizing the securitization process of loans**



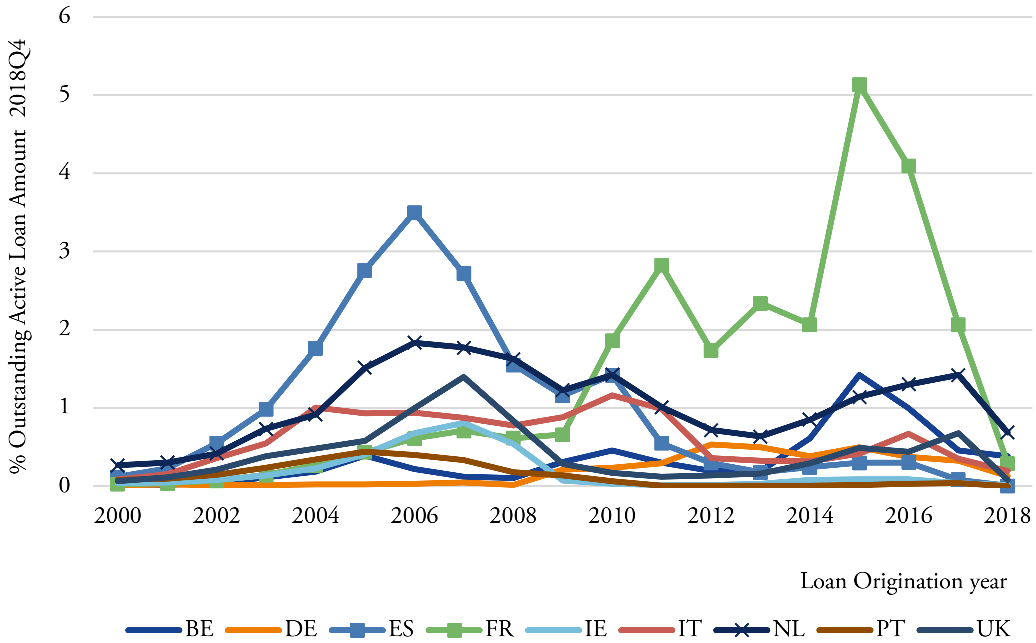

**Source:** Own elaboration.

**FIGURE 3.**
**Evolution of the outstanding active loans amount 2014 -2018. Quarterly date. Value at the end of the period. Only RMBS data**




**Source:** European DataWarehouse, EDW.

**FIGURE 4.**
**Breakdown (% over total value) of outstanding active loan value in 2018 Q4 by origination date. Only RMBS data**




**Source:** Own elaboration with European DataWarehouse (EDW) data.

# 3. Methods and materials

## 3.1. Description of the EDW/ECB dataset

European DataWarehouse (EDW) is a data repository where securitized assets info is collected, validated, and made available for download detailed, standardized and asset class specific loan-level data (LLD) for Asset-Backed Securities (ABS) transactions and private whole loan portfolios. According to EDW, the number of active loans in the EDW database was 35.5 million in Q1 2019, irrespective of the date of issuance, while the outstanding balance of active (outstanding) loans was €867 billion. This is a huge amount of very detailed information for quantifying interregional financing flows.

As the data come from securitization of loans, it is needed to consider the characteristics of this financial operation. In particular, it is important to remark that securitization is an operation that does not affect all loans, and therefore, the data can exhibit some degree of lack of representativeness in some credit segments. Another important fact is the limited number of financial institutions that are active in the securitization market as this type of operation is not accessible to small banks. Moreover, in some countries, securitization is an unusual operation. Therefore, some countries and financial institutions are not represented in the database.

Table 2 shows the evolution of the amount of active loans in the EDW database and their geographical distribution. Two main features should be highlighted. First, the amount of active loans is decreasing, as new deals are not large enough to offset the effect of loan repayments over time (the average amount per deal has decreased from €1.5 billion to €1.3 billion). And second, there are significant differences across countries that are unrelated to the country's economic importance as measured by GDP. This latter feature indicates the role played by institutional factors (regulation, banking culture...) on the practice of securitization between countries.

**Table 2.**
**Active loans amounts. 2013-2019. Millions €**

| | 2013-Q4 | 2014-Q4 | 2015-Q4 | 2016-Q4 | 2017-Q4 | 2018-Q4 | 2019-Q1 |
|---|---|---|---|---|---|---|---|
| **Austria** | - | - | - | - | - | - | - |
| **Belgium** | 77,758 | 70,102 | 66,770 | 65,536 | 64,648 | 64,730 | 67,454 |
| **Germany** | 29,990 | 55,936 | 73,715 | 79,703 | 85,867 | 84,637 | 84,875 |
| **Spain** | 138,276 | 142,997 | 136,621 | 145,929 | 149,804 | 136,795 | 131,588 |
| **Finland** | 440 | 692 | 706 | 860 | 1,086 | 1,174 | 1,022 |
| **France** | 142,034 | 125,323 | 142,776 | 147,259 | 132,714 | 135,759 | 147,436 |
| **Ireland** | 38,490 | 36,802 | 33,561 | 34,387 | 28,259 | 21,822 | 21,950 |
| **Italy** | 133,481 | 143,827 | 133,222 | 128,042 | 130,235 | 131,529 | 126,658 |
| **Luxembourg** | - | - | 2,000 | 2,000 | 2,000 | 2,140 | 2,140 |
| **Netherlands** | 251,552 | 235,259 | 212,259 | 185,487 | 180,902 | 165,100 | 165,172 |
| **Norway** | 181 | 189 | 154 | 90 | 42 | 12 | 10 |
| **Portugal** | 32,532 | 29,818 | 26,623 | 24,665 | 25,002 | 21,338 | 19,777 |
| **Sweden** | - | - | - | - | - | - | - |
| **United Kingdom** | 172,070 | 184,262 | 154,720 | 99,433 | 83,317 | 94,595 | 99,201 |

**Source:** EDW Data availability report 2019Q1. All loans valued in Q4 unless data for 2019 year.

In terms of risk transfer, the bank is likely to securitize only high-quality loans and retain the riskiest tranche (first loss piece) due to information asymmetries between the issuing bank and investors. Therefore, the relationship between securitization and bank risk is ambiguous. This policy ensures that the characteristics of the securitized loans are skewed towards the characteristics of high-quality loans, and therefore the loans included in the financial vehicle are not fully representative of all loans.

Summing up, securitisation affects the dataset quality in (EDW, European Datawarehouse data availability report q1 – 2019, 2019):

- Loans are securitized only if they meet the "eligibility criteria" and not to make the dataset representative of the financial flows in Europe.
- Lenders are only represented in the database if one of their deals is active. It is important to keep in mind that not all the lenders are securitizing loans to the same extent.
- Loans may be subject to repurchase by the originator after a loan modification. Thus, loans leave the securitized pool when they are repurchased.
- The securitized loans in the database may have been originated long before their securitization. The composition of the pool is therefore subject to "survivor bias", as securitization eligibility criteria typically exclude delinquent loans at deal origination. The securitized pool may therefore perform better than the average loans of the same vintage and originator. This "survivor bias" can be exacerbated by loan repurchases when a loan is repurchased by the originator from the securitization fund. This can occur when a securitized loan may need to be repurchased for technical or performance reasons.
- When a pool has amortized to less than 10% of its original amount, the originator can repurchase it using a "clean-up call" that interrupts the time series for the remaining loans, even if they have not yet been fully repaid or the workout process is not yet complete.

From a practical point of view, the limitations mentioned above make it necessary to be cautious about the representativeness of the data. Not all loans of a given type are included. Another caveat is the possible existence of breaks in the series due to changes in the composition and valuation of the loans included in the EDW reporting financial vehicles. Extracting data at different points in time could show differences (fortunately of little significance) due to these changes in deal composition. When querying data in the EDW database, the following time dimensions should be considered: date of query, reporting period (deals should update information at least quarterly), and origination date of loans.

**TABLE 3.**
**Summary of data issues**

| Variable | Issue | Possible solution |
|---|---|---|
| Lender information | In most cases, only NAME, EDCODE | Need additional info about lenders |
| | No geographic info directly | |
| Borrower | NUTS3: Auto, Consumer Finance, Lease (obligor) , Public Sector, RMBS (warranty location) | Additional info about borrowers |
| | NUTS2: SME (warranty and loan) | |
| | Country: Credit card (indirectly), CMBS (loan) | |
| Financial flow | Amount of loanCountry: Credit card (indirectly), CMBS (loan) | No relevant issues, only error treatment is needed |
| Financial flow | Origination date<br>Amount of loan | No relevant issues, only error treatment is needed |
| | Origination date | |

**Source:** Own elaboration based on EDW database.

As mentioned above, the EDW contains additional complexities compared to most of the territorial datasets usually analysed in spatial economic analysis. One corresponds to the purely geographical dimension and the other to the temporal one. We summarize here (Table 3) the most relevant aspects of the treatment given in this article, leaving the details to the Appendix.

As mentioned above, several agents are involved in the securitization process. Therefore, different locations are involved in the financial flows. The basic variables needed to estimate interregional financial flows are the geographical location of the lender and the borrower at the NUTS 2 level, the amount of the loan issued, and the origination date. Due to anonymity issues, the EDW database does not provide all this information, but just the one corresponding to the loan amount and the origination date. However, the geographical location of the loan collateral is available at different levels (country, region, city...), which can be used as a proxy for the location of the lender. Thus, we use the collateral location as the destination of the financial flow. It is reasonable to expected that the location of the collateral and the location (residence) of the borrower will be the same in the case of mortgages on primary residences, but this is not guaranteed and there may be differences in some other cases (e.g., mortgages on land or business credit).

Geographic information in EDW database is provided using NUTS (1/2/3 digits) 2006 classification. Such information is translated into the NUTS 2016 classification. In certain cases, the reclassification is not feasible, and only country code is provided. As an indication of the relevance of the lack of identification problem in the RMBS loans data, only it has been possible to assign a NUTS 2 code to borrower location on 76.8% of the total outstanding loan value (in date 2019Q1).

The location of the lender is more problematic, as no direct information is contained in the dataset. In the EDW database, the loan originator identification is coded and there is no way to decode it. In the securitization process, a lender (a EDCODE identifies the pool) takes a set of conduit loans (originator), pools them together, and sells them as bonds. In this study, the "origin" of the financial flow will be the address of the Financial Vehicle Corporation identified by an EDCODE.

Since the EDW database does not directly provide this address (only the country is identifiable), we combine this data source with the European Central Bank (ECB) and Bank of England (BOE) registries of Financial Vehicle Corporations (FVCs) using the ISIN code that uniquely identifies each FVC. An ISIN code (International Securities Identification Code) is a 12-digit code whose primary purpose is to identify securities such as stocks and bonds.

The location of the lender is obtained by combining information on the EDCODE from the EDW database and the ISIN trade code from the European Central Bank and the Bank of England. By combining these datasets, it is possible to obtain the address where the financial vehicle is legally located. This address is geo-positioned (Lat, Long coordinates) using the Open Street map API, and then a NUTS 2 code is assigned to each EDCODE.

Regarding the temporal dimension, the EDW database contains two possible time variables: i) the date of loan origination; ii) the date of the update of the balance sheet values of the financial vehicle (FV).

According to these dimensions, there are two alternative ways of presenting the information on financial flows between European regions: the vintage approach, where we attend to the loan origination date, and the balance sheet approach, where we consider the outstanding valued of all loans irrespective of the origination date. Given that the objective of this study is to quantify cross-border financial flows and that the EDW database refers to securitized assets, it was decided to present the information according to the "balance sheet" approach. This choice is intended to ensure that the values provided truly reflect the value of the financial flow between the debtor and the creditor in each period, which includes not only the amount of the loans granted in each period, but also all the loans previously granted but not yet repaid by the debtor. In sum, the values shown on a given date are valuations of all loans securitized to date, regardless of their origination date, at their current value. The location of the borrower is proxied with the location of the collateral (RMBS) and the location of the lender is proxied by the legal address of the financial vehicle.

## 3.2. Econometric analysis

Despite the data limitations, the analysis of the drivers of regional credit demand yields interesting results. In this section we develop a simple model of regional credit demand to identify the role of some of the variables traditionally used in credit demand modelling. In this exercise, we will only consider the total volume of loans by region (destination) and year. We will consider the data of all types of loans, valued at their current value at the time considered, regardless of the year in which the loans were generated, expressing the values in millions of euros.

The database allows to build a panel data for the years 2014-2018 and 166 European NUTS2 regions. Unfortunately, some regions do not have data for all the years considered and are removed from the panel. Remarkably, we find a notable dispersion in regional credit volumes. The maximum value of loans is located at the Italian region ITC4 in the 2014 year with a value of 67,810 million €. The minimum in the panel is AT34 with a near zero value of 0.000386 in 2016.

The demand for credit is mainly related to the level of economic activity. The purchase of durable consumer goods is usually financed by loans, and the demand for housing by owner-occupiers is usually financed by mortgages, which makes both types of loans highly pro-cyclical. As a suitable variable to measure the level of activity, the GDP or the unemployment rate at regional level NUTS2 is considered. On the other hand, the volume of credit is negatively influenced by the perceived risk of the operation. This risk perceived by the lender depends mainly on factors related to the individual characteristics of the debtors (personal income, type of employment contract, guarantees, etc.), although it may also be due to adverse macroeconomic characteristics affecting the general credit policy of financial institutions.

**Table 4.**
**Regional credit demand: selected explanatory variables**

| Variables | Description |
|---|---|
| Densityit | Population density by NUTS 2 region (Persons per Km2). Eurostat |
| Ageit | Median age of regional population [MEDAGEPOP]. Eurostat |
| GDPit | Regional GDP. ESPON Database. |
| Unemployment rateit. | Unemployment rate by NUTS2 regions. Eurostat |
| Wage (real) it | Real Wage. Own calculations based on Eurostat data: Compensation of employees by NUTS 2 regions, and Employment by region. Wage is divided by country Purchasing power parities (PPPs) from Eurostat. |
| BUSINESSi | Business sophistication. European Commission 2019. Composite index by regions composed by Employment in the "Financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities" sectors (K-N) as % of total employment. GVA in the "Financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities" sectors (K-N) as % of total GVA SMEs with innovation co-operation activities as share of total number of SMEs, SMEs introducing marketing or organizational innovation as share of total number of SMEs. Only data for 2019 year. |
| RCIi | Regional competitiveness index by NUTS2 European Commission 2019. Only data for 2019 year |

**TABLE 4. CONT.**
**Regional credit demand: selected explanatory variables**

| Variables | Description |
|---|---|
| Housing Prices $_{ct}$ | Residential property prices - Real - Index, 2010 = 100. BIS (Bank for international Settlements). Only country data. |
| NPL $_{ct}$ | Bank nonperforming loans to total gross loans (%). Country level data World Development Indicators. World Bank |
| COASTi | Dummy variable that takes the value of 1 if the NUTS2 region is located in the coastal zone. |

**Source:** Own Elaboration with EDW data.

Since the credit flows analysed are measured at the level of NUTS 2 regions and are mainly composed of securitized mortgages, it is necessary to have a regional indicator of credit risk that considers personal characteristics. In our analysis, this indicator will be the real wage rate and the regional median age, which not only have a direct impact on the likelihood that a loan applicant will be considered insolvent by a credit institution but are also indicators of regional economic activity. Another risk indicator considered in this analysis is the non-performing loan ratio, but this indicator is measured only at the country level, so it will only capture country-specific factors.

In addition to these variables, other factors are expected to influence the level of credit in each NUTS 2 region when explaining regional credit volumes. Among these factors, we will include population density to see if different patterns of credit demand are observed between regions with low and high population density. Another variable included aims to capture specific regional factors such as the Regional Competitiveness Index published by the European Commission and the Business Sophistication Index as a measure of the weight of the financial sector and real estate activities at the regional level.

We include residential property prices published by the Bank for International Settlements, given our focus on securitized mortgages. This variable is measured at the country level as an index with 2010=100 and therefore only reflects the evolution of house prices, but it is uncapable of capturing the region with the highest prices. To the best of our knowledge, there are no equivalent indicators at the regional level with the necessary spatial coverage.

For simplicity, and considering the exploration nature of this analysis, we study two alternative panel data specifications, one using random effects (equation 1) and the other fixed effects (equation 2).

$$L_{i,t} = \beta_0 + X_{i,t}\beta + X_i\beta' + X_{ct}\beta'' + T_t + v_i + \varepsilon_{i,t} \quad (1)$$

$$L_{i,t} = \beta_0 + X_{i,t}\beta + X_i\beta' + X_{ct}\beta'' + T_t + \varepsilon_{i,t} \quad (2)$$

Where $L_{i,t}$ is the volume of loans (log of the current value in year t of total loans reported in the EDW database) in region i and year t. $X_{i,t}$ is the set of variables with regional and time variation, with values observed in region i (i=1,..,n) and time t (t=1,…,T) (Unemployment rate, regional GDP, median age, population density, and real wage rates). $X_{ct}$ is the set of variables that are observed at country level in year t, as he *Housing Prices*, or the Non-Performing loans ratio. $T_t$ are yearly time effects, included to capture common trends in regional credit demand, as for example the potential effects of the ECB's APP program. Finally, it is necessary to remark that, since $X_i$ includes the variables observed at regional level, it could not be included in a fixed effect panel data specification.

In addition, to account for the possible effect of spatial dependence on interregional credit flows, two alternative specifications based on spatial error panel models with fixed effects (Elhorst, 2003) are considered.

$$L_{i,t} = \beta_0 + X_{i,t}\beta + X_i\beta' + X_{ct}\beta'' + \mu_i + \epsilon_{i,t}$$

$$\epsilon_t = \lambda W \epsilon_t + \varepsilon_t$$

where W is the n × n row-standardized interaction (Queen contiguity) or spatial weight matrix, λ represents the intensity of spatial autoregressive parameter and $\varepsilon$ is a T × 1 idiosyncratic error vector of well-behaved disturbances.

## 4. Results

### 4.1. Descriptive analysis

Figure 4 shows the financial linkages at the regional level derived from the EDW data by applying the location methodology of flows described in the annex, including all types of loans. As can be seen, the financial flows in the database are mainly internal flows with origin and destination in the same country, as in the case of Spain or Italy. However, the figure also highlights the importance of Luxembourg as a financial centre, which indeed has significant links with the Netherlands, the United Kingdom, Germany, and Austria (see Table 5 for the detail).

**Figure 4.**
**Interregional financial flows. Current Loan values (mean, all dates)**

**Source:** own elaboration based on EDW dataset. Note: Only financial flows with origin and destination identified at NUTS2 level.

Moreover, Figure 5 maps the spatial distribution of the outstanding value of the loans in 2018Q4 included in the dataset. The regional distribution of loans clearly shows similar patterns in nearby regions, with a significant spatial correlation (Moran 0.3006, p=0.001). Focusing on more local patterns, results show different patterns. In the case of the French, Italian and Spanish regions, location in coastal areas and the capital of the state seem to boost the credit levels of nearby regions. The latter factor is also observed in the case of Portuguese regions. In the case of the Italian regions, it also seems evident that the northern regions have a higher demand for credit.

**FIGURE 5.**
**Regional distribution of loans (Valued in 2018Q4 Euro Millions) and spatial correlation measures**

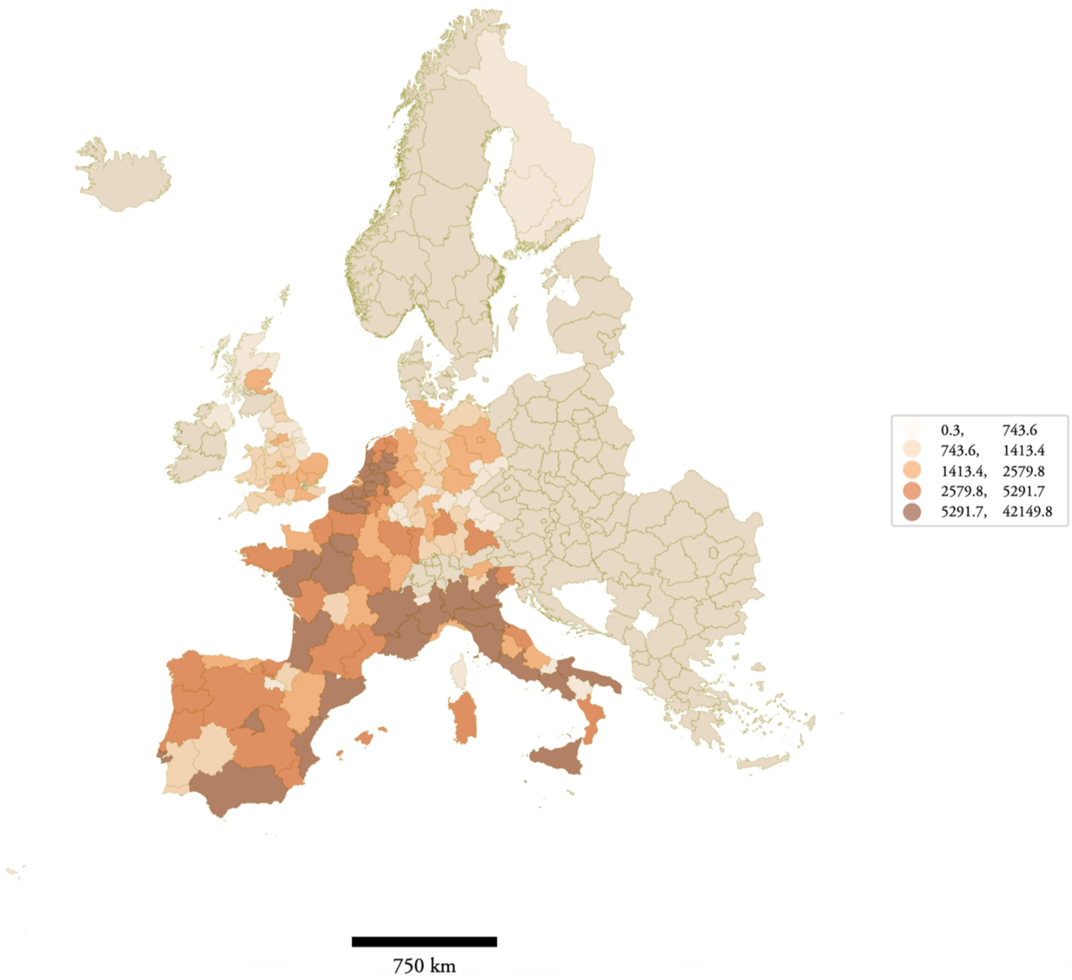
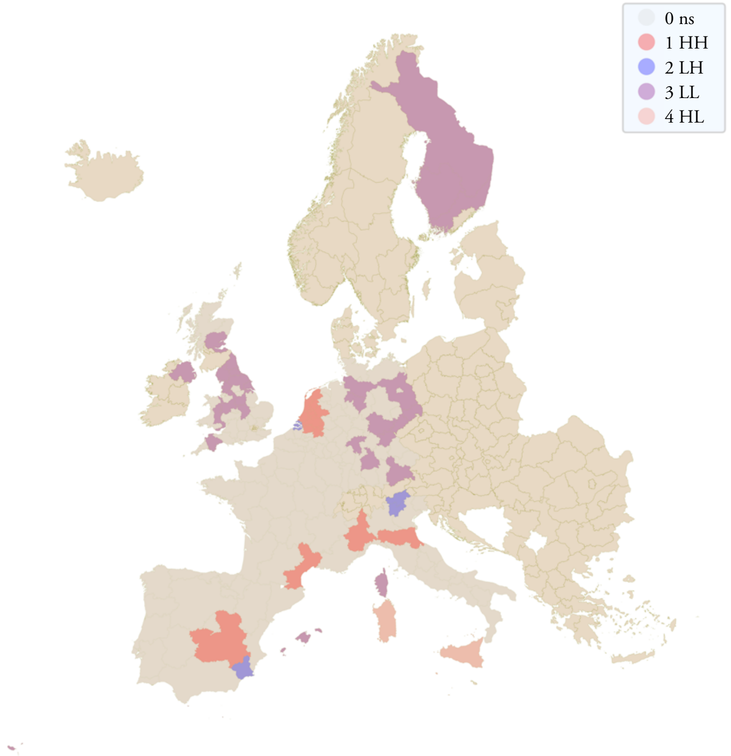
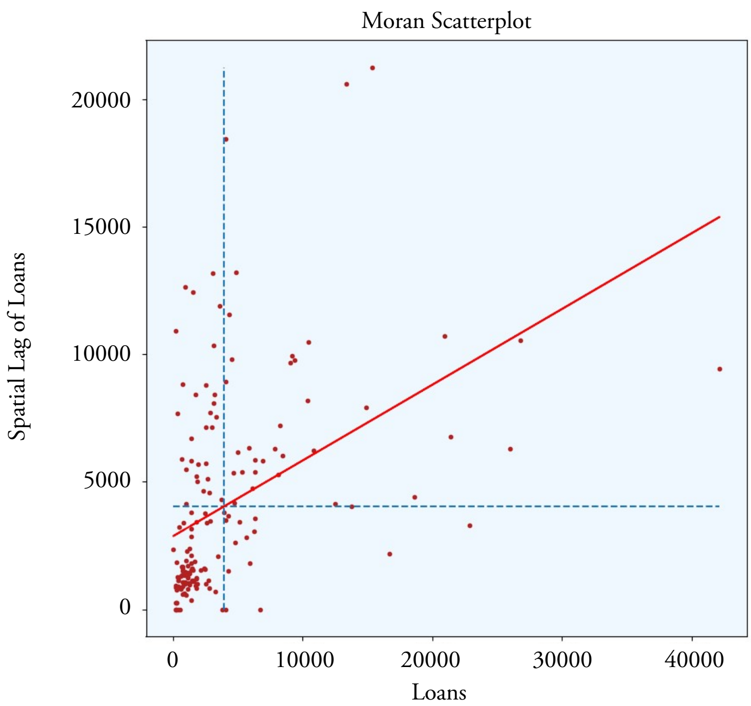


**Figure 5.** CONT.
**Spatial correlation (Queen contiguity used as spatial weights)**




**Source:** Own elaboration with EDW data. HH: High value of the variable, High value of the Spatial lag; HL: High value of the variable, low value of the Spatial lag; LH: Low value of the variable, High value of the Spatial lag, LL: Low value of the variable, Low value of the Spatial lag.

**Table 2.**
**Country location of collateral assets (rows) vs location of Financial Vehicles (columns). Number of EDCODES with identifiable location**

| All assets | BE | DE | ES | FR | IE | IT | LU | NL | PT | UK | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | | | | | | | 1 | | | | 1 |
| Belgium | 13 | | | | | | 1 | | | | 14 |
| Finland | | | | | 4 | | | | | | 4 |
| France | | | | 40 | | | | | | | 40 |
| Germany | | 28 | | | | | 55 | | | | 83 |
| Ireland | | | | | 19 | | | | | | 21 |
| Italy | | | | | | 163 | | | | | 163 |
| Luxem-bourg | | | | | | | 1 | | | | 1 |
| Netherlands | | | | | | | 4 | 65 | | | 70 |
| Portugal | | | | | 7 | | | | 32 | | 40 |
| Spain | | | 150 | | 1 | | | | | | 151 |
| Sweden | | | | | 1 | | | | | | 1 |
| UK | | | | | | | 11 | | | 17 | 28 |
| Total | 13 | 28 | 150 | 40 | 32 | 163 | 73 | 65 | 32 | 17 | 617 |

**Ne:** The location of the financial vehicle is obtained combining information about EDCODE from EDW database and ISIN deal code from the European Central Bank and the Bank of England. More details are given in the annex.

## 4.2. Econometric results

In this section, we present the results of the econometric analysis, where we model the drivers of regional credit demand using the EDW/ECB data for the period 2014-2018 and 166 European NUTS2 regions considering the total volume of credit by region (destination) and by year. The estimation results are presented in Table 6, in two alternative models, whether GDP or unemployment is included to capture the effect of economic activity on credit demand.

To start with, it is necessary to make a warning about the low goodness of fit in some specifications (mainly M1-RE; M2-RE; M3 and M4) and the high dispersion of the credit data mentioned above suggest caution in interpreting the results. At first glance, the estimated coefficients for some variables (for example, the coefficients for unemployment or population density) may seem contradictory. Recalling the singular characteristics of the dataset, it is important to keep in mind the high concentration of EDW loan data, both spatially and temporally, and by type of assets. Mortgage loans have the largest weight in the database and are highly concentrated in some regions and countries.

Interestingly, the estimation results of the specifications based on the spatial error panel model confirm the existence of significant effects derived from the proximity between regions. However, the estimated effects of the variables on credit demand are qualitatively like those obtained with classic non-spatial approaches.

As mentioned in previous sections, the case of Spain is one of the most significant due to the weight of securitized mortgages in the database whose collateral is in Spain. Probably, the signs of the coefficients estimated for the unemployment and the population density is driven by some features of the database commented before, such as the biased presence of certain countries in the database. Therefore, it is necessary to recognize that the results are strongly conditioned by the quality of the information available and that the credit data at the European level are not sufficiently representative to guarantee the robustness of the results.

TABLE 6.
**Loan demand drivers. Summary of panel data estimations**

| | Model 1 (M1) | | | | Model 2 (M2) | | | | Model 3 (M3) | | Model 4 (M4) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Panel OLS | | Random Effects | | Panel OLS | | Random Effects | | Spatial error model | | Spatial error model | |
| C | 1.431100 | | 3.498400 | | -2.918100 | | -0.064200 | | | | | |
| | 3.922200 | - | 2.902100 | - | 3.079000 | - | 2.726800 | - | | | | |
| Real Wage | 0.167800 | ** | 0.019800 | | 0.122800 | ** | 0.029200 | | 0.0177651 | ** | 0.0196843 | ** |
| | 0.070900 | - | 0.031100 | - | 0.041100 | | 0.028900 | - | 0.0068125 | - | 0.0069012 | - |
| Pop- density | 0.000045 | | 0.000200 | | -0.000093 | | 0.000500 | ** | 0.0003626 | * | -0.0005165 | ** |
| | 0.000200 | - | 0.000300 | - | 0.000300 | - | 0.000200 | - | 0.0001885 | - | 0.0001426 | - |
| GDP | 0.000004 | | 0.000005 | * | | | | | -0.0000005 | | | |
| | 0.000003 | - | 0.000003 | - | | | | | 0.0000012 | - | | |
| Unemployment | | | | | 0.246100 | ** | 0.030100 | * | | | 0.0107348 | ** |
| | | | | | 0.038200 | - | 0.017000 | - | | | 0.0052535 | - |
| Age | 0.147600 | ** | 0.026500 | | 0.161100 | ** | 0.095700 | * | 0.0004279 | | -0.0195904 | |
| | 0.054600 | - | 0.063900 | - | 0.042800 | - | 0.052300 | - | 0.0175007 | - | 0.0188209 | - |
| Business | 0.507900 | | 1.385800 | | 0.484100 | | 1.512900 | | | | | |
| | 0.385100 | - | 1.216600 | - | 0.408200 | - | 1.091200 | - | | | | |
| RCI | 0.417100 | | -0.082000 | | 2.877600 | ** | -0.054200 | | | | | |
| | 0.477200 | - | 2.006100 | - | 0.484700 | - | 1.739900 | - | | | | |
| Housing prices | -0.071400 | ** | 0.002900 | | -0.041200 | ** | 0.006000 | * | -0.0087334 | ** | 0.0024116 | |
| | 0.013000 | - | 0.002100 | - | 0.010300 | - | 0.003400 | - | 0.0019105 | - | 0.0018709 | - |
| NPL | 0.070300 | ** | 0.003400 | | 0.144400 | ** | 0.001500 | | -0.0108617 | ** | -0.021131 | ** |
| | 0.031700 | - | 0.011800 | - | 0.023900 | - | 0.011000 | - | 0.0051043 | - | 0.005504 | - |
| Coast | 0.516700 | ** | 1.427900 | ** | 0.438500 | ** | 1.313200 | ** | | | | |
| | 0.230400 | - | 0.491400 | - | 0.201300 | - | 0.396000 | - | | | | |

**TABLE 6. CONT.**
**Loan demand drivers. Summary of panel data estimations**

| | Model 1 (M1) | | | | Model 2 (M2) | | | | Model 3 (M3) | | Model 4 (M4) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Panel OLS | | Random Effects | | Panel OLS | | Random Effects | | Spatial error model | | Spatial error model | |
| lambda (Spatial error model) | | | | | | | | | 0.7979349 | ** | 0.7086296 | ** |
| | | | | | | | | | 0.0194901 | - | 0.0256049 | - |
| R-squared | 0.4674 | | 0.0698 | | 0.5661 | | 0.0713 | | 0.0054 | | 0.1011 | |
| Log-likelihood | -1433.6 | | 341.88 | | -1354.3 | | 326.22 | | -1662.012 | | -1769.424 | |
| Cov. Est. | Clustered | | Clustered | | Clustered | | Clustered | | | | | |
| No. Observations | 774 | | 774 | | 774 | | 774 | | 515 | | 525 | |
| Haussman Test | p-Value: 0.01761 | | | | p-Value: 0.00000 | | | | | | | |
| Effects: | Time | | Time | | Time | | Time | | Entity | | Entity | |

**Source:** Own elaboration. Note: Panel models are estimated with time effects. Std. errors are indicated below the estimated coefficients (** significant al 5% level, * significant at 10% level). Spatial error model estimated using PySAL library for python (Rey & Anselin, 2007).

**TABLE 7.**
**Loan demand drivers. Robustness check. Pooled regression and Cross-section regression (mean values of the variables at regional level) estimation**

| | Model 5 | | Model 6 | | | Model 7 | | | Model 8 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pooled | | Pooled | | | Cross Section | | | Cross Section | |
| C | -0.44710 | | -5.17710 | ** | | -5.80130 | * | | -8.26720 | ** |
| | 1.28670 | - | 1.27860 | - | | 3.33360 | - | | 3.11580 | - |
| Real Wage | 0.17270 | ** | 0.14650 | ** | | 0.25540 | ** | | 0.17340 | ** |
| | 0.01480 | - | 0.01400 | - | | 0.03460 | - | | 0.03570 | - |
| Pop- density | 0.00009 | | 0.00003 | | | 0.00030 | | | 0.00007 | |
| | 0.00020 | - | 0.00010 | - | | 0.00040 | - | | 0.00040 | - |
| GDP | 0.00001 | ** | | | | 0.00000 | * | | | |
| | 0.00000 | - | | | | 0.00000 | - | | | |

**TABLE 7. CONT.**
**Loan demand drivers. Robustness check. Pooled regression and Cross-section regression (mean values of the variables at regional level) estimation**

| | Model 5 | | Model 6 | | | Model 7 | | | Model 8 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pooled | | Pooled | | | Cross Section | | | Cross Section | |
| Unemployment | | | 0.21090 | ** | | | | | 0.27960 | ** |
| | | | 0.01800 | - | | | | | 0.05090 | - |
| Age | 0.16910 | ** | 0.18780 | ** | | 0.31970 | ** | | 0.27220 | ** |
| | 0.02590 | - | 0.02440 | - | | 0.06950 | - | | 0.06380 | - |
| Business | 0.58550 | ** | 0.55660 | ** | | 0.70900 | | | 0.48800 | |
| | 0.19520 | - | 0.18250 | - | | 0.51670 | - | | 0.47310 | - |
| RCI | -0.06500 | | 1.85640 | ** | | -0.12790 | | | 2.92260 | ** |
| | 0.26670 | - | 0.28650 | - | | 0.73720 | - | | 0.83500 | - |
| Housing prices | -0.06250 | ** | -0.03220 | ** | | -0.10380 | ** | | -0.05780 | ** |
| | 0.00530 | - | 0.00560 | - | | 0.01580 | - | | 0.01700 | - |
| NPL | 0.04630 | ** | 0.10730 | ** | | 0.01030 | | | 0.12330 | ** |
| | 0.01810 | - | 0.01660 | - | | 0.05530 | - | | 0.05120 | - |
| Coast | 0.52460 | ** | 0.44210 | ** | | 0.82190 | ** | | 0.71270 | ** |
| | 0.12570 | - | 0.11790 | - | | 0.32480 | - | | 0.29970 | - |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| R-squared | 0.4508 | | 0.5151 | | | 0.6164 | | | 0.6718 | |
| Log-likelihood | -1449.2 | | -1401 | | | -335.95 | | | -322.98 | |
| Cov. Est. | Unadjusted | | Unadjusted | | | Unadjusted | | | Unadjusted | |
| No. Observations | 774 | | 774 | | | 166 | | | 166 | |

**Source:** Own elaboration. Std. errors are indicated below the estimated coefficients (** significant al 5% level, * significant at 10% level).

Among the specifications considered, the only robust result seems to be the negative effect of housing prices on credit demand and the positive effect of real wages. In all cases, the effect of regional median age has a negative impact on credit demand. For the remaining variables, the sign of the coefficients and their significance depend on the panel data specification. The coefficient of the NPL variable seems to have the correct sign in the models that consider spatial correlation, although in the case of population density the results are far from robust.

## 5. Conclusions and limitations

There is clear evidence of a growing degree of regional integration in terms of trade of goods and services in Europe. However, the measurement of the corresponding to capital flows is scarce, due to lack of data. The aim of this study is to explore a new dataset on securitized asset-backed loans in Europe, recently launched by the ECB, and managed by the EDW.

Our analysis is very transparent in its description of the advantages and disadvantages of these novel dataset. Most of the flows included in the dataset are intra-national. However, while some countries are over-represented in the data in terms of the value of loans/GDP ratio, in other cases, such as German regions, there is no information on the type of loan that predominates in the EDW database, i.e., RMBS. Moreover, within each country, it is not possible to break down the origin of the flows by the different branches that multi-regional financial institutions have. Almost all flows are attributed to the head office of the financial institutions issuing the assets. Consequently, the "fuzzy" picture obtained from our research emphasizes the intra-national nature of financial flows, as well as the high concentration in the source regions within each of these countries.

Given the limitations, the results obtained provide interesting information on the spatial pattern of the loans included and give some indications on the degree of fragmentation of the financial system in Europe. In particular, the results show that the securitization market in Europe is not yet fully developed, as not all EU countries participate to the same extent, despite its benefits in providing liquidity and redistributing risk.

Given the innovative but limited scope of this analysis, the need for further extensions is clear. The study of the integration of the European financial markets, and in the euro area, is essential in an environment of frequent tensions in the global and European bank system. More information is needed to determine whether this decline can be explained by more local factors, given the enormous regional concentration that can be deduced from the EDW data for the set of countries for which data are available. The potential effects of BREXIT on the structure of international financial flows in Europe, as well as the effect on the volume of total credit, is a key issue, given the considerable weight of the assets generated in the UK.

Given the importance of knowing more about the regional characteristics of credit flows, we believe that the European authorities should increase the quantity and quality of publicly available data. Information from cross-border payment systems (such as TARGET2), combined with the territorialized credit information currently published by the ECB and national central banks, can help to shed new light on these interrelationships across regions.

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# Articles

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Articles

# Dynamic interaction between permanent and temporary employment across manufacturing labor markets in the Mexican states: A structural panel VAR approach

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## Abstract:

México's implementation of several labor market reforms aimed to stimulate the flexibilization of labor relationships have brought long-standing concerns among scholars and governmental authorities about a displacement process of permanent by temporary jobs. In this regard, this manuscript aims to respond whether the dynamic interaction between permanent and temporary employment across Mexican states describe a substitution or complementary relationship. By means of implementing a structural panel vector autoregressive model, our estimation results demonstrate that a combination of both types of interaction, substitutive and complementary ones, prevail across manufacturing labor markets at state level. Moreover, a marked heterogeneity among estimated dynamic responses suggests that incentivizing permanent employment would induce stronger substitution effects on its temporary counterpart than, for example, substitution of permanent job positions arising when incentivizing temporary employment.

**Keywords:** Permanent employment; temporary employment; regional labor markets; México; structural panel VAR.
**JEL classification:** C23; E24; J0; L60; R10.

## Interacción dinámica entre el empleo permanente y temporal en los mercados manufactureros regionales de los estados mexicanos: un enfoque de VAR estructural en panel

## Resumen:

La implementación de varias reformas laborales en México, cuyo propósito fue estimular la flexibilización de las relaciones laborales, ha atraído un interés duradero de académicos y autoridades gubernamentales acerca del desplazamiento de empleos permanentes por empleos temporales. En tal sentido, esta investigación tiene el propósito de responder si la interacción dinámica entre los empleos permanentes y temporales en los estados mexicanos describen una relación sustitutiva o complementaria. Mediante la implementación de un modelo de vectores autoregresivos estructurales en panel, nuestras estimaciones demuestran que ambos tipos de interacción prevalecen en los mercados regionales de trabajo manufacturero con marcadas asimetrías que sugieren las políticas para fomentar el empleo permanente tendrían una mayor efecto sustitutivo que aquéllas diseñadas para promover el empleo temporal.

**Palabras clave:** Empleo permanente; empleo temporal; mercado laboral regional; México; Panel VAR estructural.
**Clasificación JEL:** C23; E24; J0; L60; R10.

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## 1. Introduction

During the last decades, both developed and developing economies have adopted wide labor market reforms aiming at providing the economic incentives and institutional conditions for achieving less rigidity in their functioning. In this regard, labor market flexibility has been generally envisioned as a means for firms' adaptation to market fluctuations, both expected and unexpected, to cut labor costs and rise productivity (Van, 2003) as well as providing unemployment alleviation (OECD, 1994). As a result, new types of flexible labor contracts have emerged, importantly, temporary employment which has exhibited a generalized increase along with significant variations across the countries and regions that have gradually embraced flexible-oriented labor market policies.

The evidence in this regard indicates, for example, that the share of temporary workers in total employment has increased from 9 to 14 percent in the European Union over the last three decades with Spain and Poland showing rates as high as 25 percent in 2014. Similarly, these figures have also increased moderately in most Latin American countries with both, Ecuador and Perú, achieving proportions slightly above 50 and 60 percent in 2013, respectively (International Labour Organization, 2016).

In the case of México, a deep process of reforms aiming at opening the economy and deregulating markets as well as reprivatizing public firms has been in curse since the mid-eighties (Cárdenas, 1996; Moreno & Ros, 2009). Even if the labor reform was approved until late 2012, different forms of more flexible labor contracts were in place as a means for improving the competitiveness and growth of the economy (Secretaría de Gobernación, 2013). Indeed, the corresponding government administrations not only allowed these new contracts but encouraged them to also improve the attractiveness of the economy (De la Garza, 2010; Mendoza, 2017). Consequently, according to official information published by the Mexican Institute of Social Security (IMSS, for its acronym in Spanish), the share of permanent employment in the total one has decreased from 95 percent to 86 percent in a fifteen-year period thus reflecting the increasing importance of more flexible employment contracts.[2]

Although the increasing labor market flexibilization encompassing global trends may be seen as a successful component of the market reforms package in México, as it may have contributed to boosting exports, foreign direct investment, employment and output, some concerns have recently emerged regarding its adverse effects on the population's standards of living resulting from the rise of temporary and informal jobs (González, 2012; Quintana & Garza, 2017). Moreover, a labor market issue that has received little attention from scholars is the identification of patterns regarding the dynamic interaction between the permanent and temporary components of employment resulting from the implemented labor market reforms within the Mexican states.

Recent data show that shares of temporary jobs were lower than 10 percent in most Mexican states in 2003, with only six of them displaying higher shares. However, because of high growth rates, this situation reversed up to the point where most of them showed two-digit shares of temporary employment, with figures over 20 percent in some cases over the subsequent years; state permanent employment, on the contrary, has experienced lower or even negative average growth rates over the same period. These patterns reflect significant heterogeneity in the adoption of labor policy reforms across the Mexican states, thus making difficult to distinguish the predominant strategic interaction between these two types of employment, that is, whether states' economic agents have pursued a substitution or a complementation process between permanent and temporary jobs.

In this context, the aim of this paper is to identify the type of interaction prevailing between temporary and permanent employment across the Mexican states over the period 2003-2022. Particularly, we intend to respond the following questions: does the dynamic interaction between permanent and temporary employment describe a substitution or a complementary relationship? And, given the relative stickiness of each type of employment,[3] is this interaction symmetric or asymmetric? To answer these

[2] See its website at www.imss.gob.mx.

[3] For example, permanent jobs may be less responsive to changes in temporary jobs due to the existence of long-lasting labor contract or costs of hiring and firing.

questions, we use a structural panel vector autoregressive model[4] as proposed by Pedroni (2013), which allows us to investigate the dynamic response of the labor market variables to structural shocks in a panel setting thus useful in accounting for the observed heterogeneous behavior in the labor markets of the Mexican states.[5] In particular, this methodology will be useful to investigate whether variations in a type of manufacturing employment would subsequently induce substitution or complementary effects on the other type for each state, conditional on the possibility of adjustments in additional variables, such as output.

The rest of this paper is organized as follows: after the introduction, we present a brief literature review on some important tendencies in the labor market and, mainly, the interaction between permanent and temporary employment at international level as well as some of the major recent changes in the Mexican labor market. Afterwards we present data about the dynamics of permanent and temporary employment in Mexico and its states. Next, we present the main features of the econometric methodology, followed by the exposition and discussion of the most important findings; finally, the conclusions are stated.

## 2. Literature review

The dynamics of regional labor markets has received significant attention in the specialized literature.[6] One research area that has received some attention recently is the identification of significant spatial dependence in the emergence of "low" and "high" unemployment (employment) clusters in the European Union (Overman & Puga, 2002), Italy (Cracolici et al., 2007; Patacchini & Zenou, 2007)), the United Kingdom (Patacchini & Zenou, 2007) and Spain (Cuéllar-Martín et al., 2019), which is explained by factors such as migration, employment demand, human capital availability, neighboring effects and productive structure among others. In turn, another set of studies have highlighted regional differences in Okun's Law, which states a negative relationship between the unemployment rate and the growth rate of output, in Spain (Bande & Martín-Román, 2018; Porras-Arena & Martín-Román, 2019), the United States (Guisinger et al., 2018) and Europe (Maza, 2022), for example. By using different methodologies, these studies report short-run and long-run negative relationships explained by gender and age, productivity and productive structure as well as the magnitude of self-employment and part-time employment and the severity of long-term unemployment among others. It is important to mention that not all of these studies give account of spatial spillovers.

Notwithstanding, one area that has received relatively little attention is the analysis of the dynamics and interaction of permanent and temporary employment despite the last decades have witnessed a significant increase of temporary employment resulting from the successive deregulation of the labor market in several countries with the aim of increasing overall employment and improving competitiveness of firms. In fact, mot existing papers have studied this process at a national level. Particularly, it has been argued that in a more competitive and globalized environment, temporary labor contracts have been used as a mechanism for firms to gain flexibility to face shocks and cut down costs (Vidal & Tigges, 2009; Cooke & Zeytinoglu, 2004). In addition, temporary jobs are associated to definite and short periods of time, which allows firms to respond faster to anticipated and unanticipated exogenous or policy shocks (Jahn & Bentzen, 2012). Furthermore, firms might favor temporary contracts to seek and screen qualified workers for permanent posts, which helps them to reduce hiring and recruitment costs, as well as to fulfill specific tasks of a temporary nature (Hirsch & Mueller, 2012; Bryson, 2013).

Nonetheless, although temporary employment can contribute to a better performance of firms, it may also have several disadvantages for workers. Specifically, greater flexibility of firm is based on short-

[4] This model has been mainly used in macroeconomics and finance to deal with the dynamics of phenomena involving heterogeneous units (Canova & Ciccarelli, 2013).

[5] This model allows us to estimate the dynamic response of each variable to shocks to the others through the impulse response functions within each state. Hence, the model does not consider spatial interactions, a feature that can be addressed in other frameworks, such as spatial panel data models.

[6] See Betcherman (2012), Moretti (2011) and Eichhorst et al. (2017) for surveys on the main transformations and results in different labor markets.

time contracts for workers, which may generate more job volatility and greater employment risk (Antoni & Jahn, 2009), while lowering costs has meant firms to pay lower wages and less additional benefits (Antoni & Jahn, 2009; Andersson & Wadensjö, 2011)[7] as well as to invest less in human capital (Bryson, 2013). In addition, it seems that temporary jobs are rarely steppingstones into permanent jobs (Kvasnicka, 2009; Autor & Houseman, 2010). Furthermore, the international evidence shows that even if labor market reforms have contributed to increase total employment, firms may be replacing permanent jobs by temporary ones as a systematic strategy to gain competitiveness (Cooke & Zeytinoglu, 2004; Vidal & Tigges, 2009; Jahn & Weber, 2016), which has worried both scholars and policy makers.

In the case of México, the labor market has also experienced deep transformations over the last decades after this country embraced a development model based on an open, market-oriented economy in the early eighties. In order to overcome the long-run restrictions to grow, México got involved in a wave of reforms to liberalize international trade and foreign investment and reprivatize public enterprises, among others, in order to boost productivity and base economic growth on the external sector by increasing manufacturing exports and attracting more foreign direct investment (Aspe, 1989; Moreno & Ros, 2009; Autor/a, 2014).

In this context, manufacturing firms restructured their productive processes by introducing new technologies and reorganizing their administrative models in order to gain greater flexibility within plants.[8] These processes were facilitated by the incentives provided by the government and the availability of infrastructure and productive factors, especially different types of qualified workers that could be hired by low wages (Chong-Sup, 2002; Amoroso et al., 2011). Also, firms increasingly relied on temporary workers, who were hired for specific short-time periods or activities that usually received lower wages and less benefits than permanent workers. Furthermore, outsourcing, commonly grounded on temporary jobs as well, has become an important source of labor supply to develop non-qualified activities at low costs (García, 2010; De la Garza, 2010; Mendoza, 2017).

Overall, these strategies have generated a significant increase of temporary employment, but its dynamics or the contrast of its characteristics with those of permanent employment have received little attention in the literature. In particular, several papers have analyzed the dynamics and determinants of national aggregate and sectoral employment at the national level (e.g. López, 1999; Mejía, Reyes & Rendón, 2017; Tavares & Varela, 2019), while some others have studied the experience of the Mexican states or cities trying to identify its determinants by estimating panel data models (Escobar, 2011; Carbajal & De Jesús, 2017) or spatial panel data models (Brito & Mejía, 2020; De Jesús, Andrés & Carbajal, 2020). In general, these studies identify important determinants of employment (mainly output, productive structure and spatial spillovers, with a minor role of wages and productivity) but they do not analyze the properties and determinants of temporary and permanent employment.

As far as we know, a few papers indirectly investigate some differences between temporary and permanent employment. Loría, Ramírez & Salas (2015), for example, find that labor flexibility (measured as the ratio of temporary employment to total employment) increases the unemployment rate within the Okun's Law framework, which contradicts some of the evidence reported for developed countries. In a similar line, Mendoza's (2017) results suggest that temporary employment and real wages are positively correlated in the long run to the unemployment rate in the Mexican states, which is consistent with the findings of Loría, Ramírez & Salas (2015). In turn, Autor/a (2020) look for differentiated effects of output and real wages on temporary and permanent employment across the Mexican states. By estimating spatial panel data models, they find negative direct effects of wages on temporary employment, but the opposite in the case of permanent employment. Also, they report total positive effects of output on both types of employment.

[7] Temporary employment allows firms to reduce labor costs directly by avoiding payment of higher wages bargained in sectoral collective agreements, dismissal costs and legal expenses in case of a trial, and other benefits (OECD, 2004; Houseman et al., 2003; Jahn, 2010).

[8] The labor relation arrangements were deeply modified to be based on flexible work rules and job rotation, broadly defined job classifications, "quality circles", work teams, and other measures designed to defuse labor-employer tensions and further motivate workers. See Middlebrook (1991)

It is important to highlight that in most papers analyzing the determinants of employment in México, output and real wages are usually assumed to be exogenous, sometimes without any justification. In a strict sense, the decisions of families and firms determine the full-employment level and, afterwards, the output one. Under conventional assumptions, real wages, employment, and output are simultaneously determined. However, in the Keynesian perspective, employment is determined by the effective demand, usually measured by the aggregate output, and real wages, which may be sticky and greater than the level that empties the labor market.[9] In this framework, output and wages may be seen as exogenous.

Overall, this literature review identifies some important stylized facts of the Mexican employment both at aggregate and sectoral levels as well as at a regional dimension. Nonetheless, it also shows that the analysis of the dynamics and determinants of temporary employment versus permanent employment is rather scarce. In this context, one open question is whether permanent jobs are being replaced by temporary ones in the case of the Mexican states, an issue addressed in the rest of this paper.

## 3. Spatial distribution of permanent and temporary manufacturing employment in México

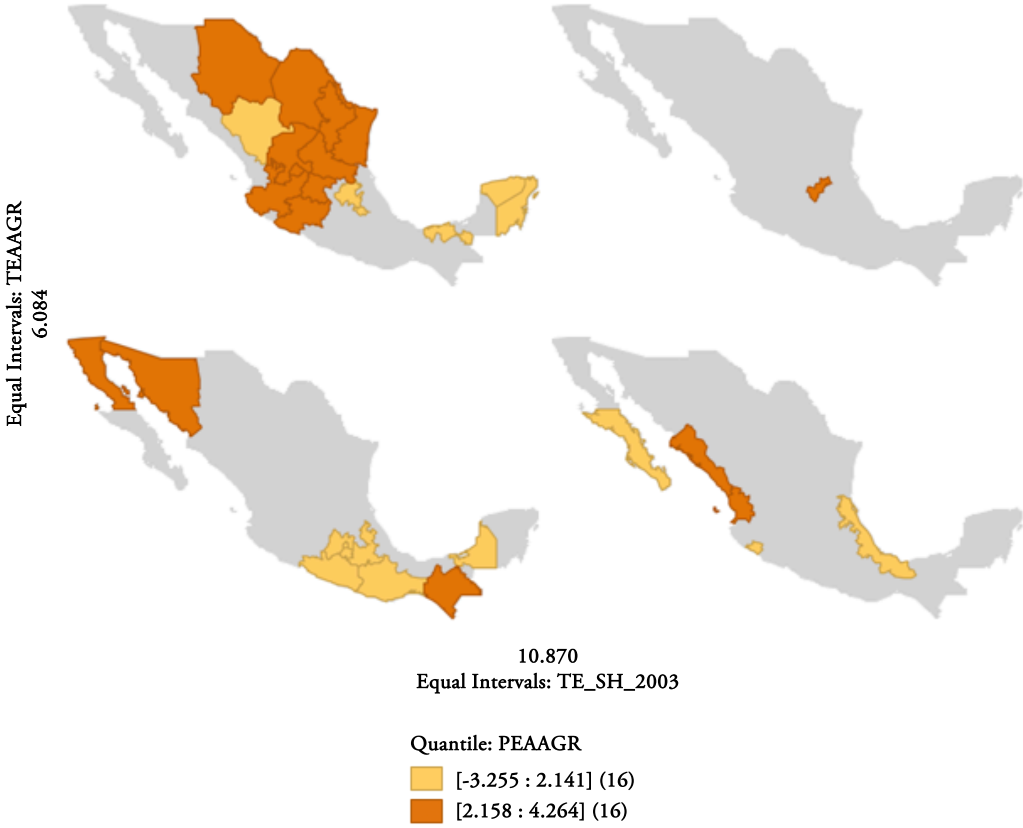
Over the last decades manufacturing employment has grown faster in northern and central-western states of Mexico (states in dark brown in maps of Figure 1) mainly because they modernized their productive activities to take advantage of a new development model and gained locational advantages after the North American Free Trade Agreement came into force in 1994 (Mejía and Torres, 2019). However, although total permanent employment has remained as the predominant form of labor contractual relationships within the manufacturing sector in México, the observed decrease in its ratio with respect to its temporary counterpart, from 18.7 to only 7.6 between 2003 and 2022, suggests that a substitutive process between both types of employment might be underway, perhaps, as a means for firms to enhance competitiveness and rise employment (García, 2010; De la Garza, 2010; Mendoza, 2017).

Furthermore, a look at the dynamics of both temporary and permanent employment across the Mexican states suggests that the transition towards more flexible labor markets has been rather distant from being uniform, as some states have accompanied this process with the preservation or even the encouragement of permanent employment contracts. In particular, the maps in Figure 1 show the spatial distribution of the annual average growth rate of permanent employment (PEAAGR), conditional on the growth rate (TEAAGR) and the share of temporary employment (TE_SH_2003), measured respectively on the vertical and horizontal axis. In this respect, most of the states in the upper-left map showing lower shares of temporary employment and high TEAAGR also had high PEAAGR, such as Chihuahua, Coahuila, Nuevo Leon, Tamaulipas, San Luis Potosi, Zacatecas, Guanajuato, Michoacan and Jalisco (dark brown). Accordingly, in the upper-right map, a similar pattern emerges in Queretaro (dark brown) where TE_SH_2003 is also high. In turn, the lower-left map suggests that permanent jobs are rapidly growing (with a low share of temporary employment) in a few states (Baja California, Sonora and Chiapas), while the lower-right map indicates that something similar is going on in Sinaloa, but with a high share of temporary jobs (in dark brown).

This process has caused a recomposition of employment within the Mexican states: while in 2003 the share of temporary employment in total employment were predominantly lower than 7.5 percent, over the subsequent two decades all states experienced an increase in those shares resulting from the introduction of firms' strategies to contract workers under more flexible forms which delivered out two-digit growth rates in a catching up process to build more flexible labor markets. Hence, these data show that permanent and temporary employment have grown at different paces reflecting processes of substitution or complementation strategies across the Mexican states.

9 See Heijdra (2017) or Romer (2019) for standard presentations of the Neoclassical and Keynesian models. Mejía & Torres (2020) and Brito & Mejía (2020) adopt a New Keynesian Economics approach to specify their empirical models.

**FIGURE 1.**
**Spatial distribution of permanent employment conditional on the growth rates and the share of temporary employment across the states of México**




TEAAGR and PEAAGR stand for the annual average growth rate of temporary and permanent employment between 2003 and 2022, respectively. TE_SH_2003 is the share of temporary employment in total employment in 2003.
**Source:** own elaboration with information from IMSS.

## 4. Methodological aspects

To investigate whether the dynamic interaction between permanent and temporary employment features a substitution or a complementation relationship in the labor markets across the Mexican states, we propose to implement a three variable structural panel VAR system (permanent and temporary employment and output), according to the methodological approach introduced by Pedroni (2013). From a practical standpoint, this methodology is useful to our investigation as it allows us to explicitly account for the observed state heterogeneous behavior and provides us with an identification scheme based on the recursiveness assumption to properly uncover the dynamic response of each type of employment within each state to structural shocks.

The economic content of this identification scheme resides upon the endogenous economic and labor variables' time of response to structural shocks by assuming that some labor variables are contemporaneously predetermined and, therefore, the specification of the panel VAR system requires us to elaborate on the economic behavior of employers and employees across states regarding the timing of their responses to unexpected structural shocks affecting labor variables.

Specifically –concurring with the work of Galí (2013), who argues that, under a New Keynesian framework, an aggregate demand-driven positive output shock would induce a positive response in the aggregate employment level, and, along with the empirical findings of Brito and Mejía (2020) and Mejía and Torres (2020) for the case of México–, we propose that both permanent and temporary employment across states in México would positively respond to unexpected positive output shocks. We assume, moreover, that both types of employment would not contemporaneously react to unexpected positive output variations but with a time lag instead as this feature seems to describe the actual economic behavior of employers and employees more appropriately. Accordingly, this lagged response of aggregate employment to demand-driven positive output variations may be explained by the decision of firms to increase current employees' working hours and decrease underutilized capacity before intending to hire new employees, which helps to avoid substantial fixed costs associated to recruitment and training involved in hiring processes until firms are convinced that the demand for their products is stable or higher (Reserve Bank of Australia, 2014), (Bell, 1981).

Additionally, firms spend longer periods of time during the process of hiring permanent employees as compared to shorter periods in hiring temporary ones. The rationale behind this assumption resides in the fact that firms may spend several weeks or even months in recruiting and training employees for permanent posts and, therefore, it is plausible that unexpected shocks to temporary employment would likely induce lagged responses on permanent employment. Conversely, however, the significant shorter periods of time required in recruiting and training temporary employees, as per weeks or days, suggest that unexpected permanent employment shocks would contemporaneously affect temporary employment.

On this ground, the structural panel VAR system is described in its expanded form as in expression (1). It is composed by an $M$ x 1 vector of endogenous variables in first differences with $M = 3$ and specified as $\Delta\boldsymbol{z}'_{it} = [\Delta pe_{it} \quad \Delta te_{it} \quad \Delta mp_{it}]'$, where $\Delta$ denotes the first difference operator and $pe_{it}$ and $te_{it}$ the permanent and temporary employment levels, respectively, while $mp_{it}$ stands for the output level. In all cases, the indexes $i$ and $t$ represent, respectively, the Mexican states and time periods, while $L$ denotes the lag operator. The exogenous error terms in the following $M$ x 1 vector $\boldsymbol{\epsilon}'_{it} = [\epsilon_{it}^{pe} \quad \epsilon_{it}^{te} \quad \epsilon_{it}^{mp}]'$ are interpreted as structural innovations capturing unexpected shocks to their corresponding endogenous variables within the structural panel VAR system. The structural parameters, $b_{MM,i}$, within the left-hand matrix of expression (1), describe the endogeneity of each variable that will be subject to the identifying restrictions.

$$\begin{bmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{bmatrix} \begin{bmatrix} \Delta pe_{it} \\ \Delta te_{it} \\ \Delta mp_{it} \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{p} \gamma_{11j}{}^{i} L^{j} & \sum_{j=1}^{p} \gamma_{12j}{}^{i} L^{j} & \sum_{j=1}^{p} \gamma_{13j}{}^{i} L^{j} \\ \sum_{j=1}^{p} \gamma_{21j}{}^{i} L^{j} & \sum_{j=1}^{p} \gamma_{22j}{}^{i} L^{j} & \sum_{j=1}^{p} \gamma_{23j}{}^{i} L^{j} \\ \sum_{j=1}^{p} \gamma_{31j}{}^{i} L^{j} & \sum_{j=1}^{p} \gamma_{32j}{}^{i} L^{j} & \sum_{j=1}^{p} \gamma_{33j}{}^{i} L^{j} \end{bmatrix} \begin{bmatrix} \Delta pe_{it} \\ \Delta te_{it} \\ \Delta mp_{it} \end{bmatrix} + \begin{bmatrix} \epsilon_{it}^{pe} \\ \epsilon_{it}^{te} \\ \epsilon_{it}^{pm} \end{bmatrix} \quad (1)$$

The the compact matrix form of expression (1) is as follows:

$$\boldsymbol{B}_i \Delta\boldsymbol{z}_{it} = \sum_{j=1}^{p} \boldsymbol{\Gamma}_{ij} L^j \Delta\boldsymbol{z}_{it} + \boldsymbol{\epsilon}_{it} \quad (2)$$

Hence, the reduced panel VAR is obtained pre-multiplying expression (2) by $\boldsymbol{B}_i{}^{-1}$,

$$\Delta\boldsymbol{z}_{it} = \boldsymbol{B}_i{}^{-1} \sum_{j=1}^{p} \boldsymbol{\Gamma}_{ij} L^j \Delta\boldsymbol{z}_{it} + \boldsymbol{B}_i{}^{-1} \boldsymbol{\epsilon}_{it} \quad (3)$$

This last equation can also be expressed as $\Delta\boldsymbol{z}_{it} = \sum_{j=1}^{p} \mathbf{R}_{ij} L^j \Delta\boldsymbol{z}_{it} + \boldsymbol{u}_{it}$ or $\mathbf{R}_i(L)\Delta\boldsymbol{z}_{it} = \boldsymbol{u}_{it}$.[10] The reduced white noise error term $\boldsymbol{u}_{it}$ is a linear combination of the structural shocks as can be seen in the expression $\boldsymbol{u}_{it} = \boldsymbol{B}_i{}^{-1}\boldsymbol{\epsilon}_{it}$, with a covariance matrix given by $E[\boldsymbol{u}_{it}\boldsymbol{u}'_{it}] = \boldsymbol{B}_i{}^{-1} E[\boldsymbol{\epsilon}_{it}\boldsymbol{\epsilon}'_{it}] \boldsymbol{B}_i{}^{-1\prime} = \boldsymbol{\Omega}_{u,i}$.

In turn, the reduced moving average representation is found by multiplying the reduced panel VAR by $\mathbf{R}_i(L)^{-1}$, which leads to:

[10] Which implies that $\sum_{j=1}^{p} \mathbf{R}_{ij} L^j = \boldsymbol{B}_i{}^{-1} \sum_{j=1}^{p} \boldsymbol{\Gamma}_{ij} L^j$ and $\mathbf{R}_i(L) = \boldsymbol{I}\text{-}\sum_{j=1}^{p} \mathbf{R}_{ij} L^j$.

$$\Delta \boldsymbol{z}_{it} = \mathbf{F}_i(L)\boldsymbol{u}_{it} \tag{4}$$

From the last expression, the structural moving average representation can, thus, be obtained by substituting the reduced shock $\boldsymbol{u}_{it} = \boldsymbol{B}_i^{-1}\boldsymbol{\epsilon}_{it}$ into the expression (4):

$$\Delta \boldsymbol{z}_{it} = \mathbf{A}_i(L)\boldsymbol{\epsilon}_{it} \tag{5}$$

The relation $\mathbf{A}_i(L) = \mathbf{F}_i(L)\boldsymbol{B}_i^{-1}$ is of relevance for our investigation as it represents the impulse responses associated to the corresponding structural shock $\boldsymbol{\epsilon}_{it}$ that describes the complete dynamic interaction between the economic and labor variables.

## 5. Identification and estimation aspects

The identification and posterior estimation of the impulse responses of the variables in the model to structural shocks for each state are based on short-run timing identifying restrictions.[11] This approach offers several methodological advantages as some studies have concluded that it delivers robust estimations to either first differencing the data or imposing cointegrating relationships (Gospodinov, Herrera and Pesavento, 2013) and, additionally, it reliably recovers and identifies the dynamic impacts of economic shocks as the sample properties of the impulse responses are robust under alternative specifications (Christiano, Eichenbaum and Vigfusson, 2006).

In this respect, the short-run identifying restrictions are imposed on the contemporaneous matrix of the dynamic structural responses $\mathbf{A}_i(0)$ in a manner that resembles the economic behavior of employers and employees across states described in the previous section.[12] To be more specific, the implemented recursive short-run restrictions thus imply that both permanent and temporary employment would respond with a time lag to unexpected demand-driven changes in the output level and that permanent employment would do so in response to unexpected temporary employment shocks, which are respectively described in the first two rows within expression (6):

$$\mathbf{A}_i(0) = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \tag{6}$$

Regarding estimation issues, we provide estimates of idiosyncratic structural impulse responses because the exploratory analysis strongly suggests the observed heterogeneity in the labor dimensions across time and space may reflect state-specific decisions of employers and employees on how they took advantage of recent national labor policy reforms. The practical procedure to obtain the idiosyncratic structural impulse responses requires, first, estimating the three variable VAR system in its reduced form for each state $i$ by using the first-differenced endogenous variables in both the vectors $\Delta\boldsymbol{z}_{it}$ and $\Delta\bar{\boldsymbol{z}}_t$, where the former comprises the raw data and the latter contains the components of the former that are common to all states, which has been labeled by Pedroni (2013) as time effects.[13] Then, we use the contemporaneous covariance matrix of the estimated reduced form residuals for both types of VARs, and jointly with the short run identifying restrictions in $\mathbf{A}_i(0)$, built the mapping relations $\bar{\boldsymbol{u}}_t = \bar{\mathbf{A}}(0)\bar{\boldsymbol{\epsilon}}_t$ and $\boldsymbol{u}_{it} = \mathbf{A}_i(0)\boldsymbol{\epsilon}_{it}$ to obtain, respectively, the estimated structural common and composite shocks. Subsequently, we calculate simple correlations between the estimated common and composite structural shocks to compute the

[11] This recursive identification scheme has been previously implemented by Bernanke & Blinder (1992), Christiano, Eichenbaum & Evans (1996), Rotemberg & Woodford (1997), and Christiano, Eichenbaum & Evans (1998a) to assess monetary policy shocks under a macroeconomic perspective. Nonetheless, the extension of the structural VAR methodology to a panel setting, as proposed by Pedroni (2013), allows its implementation to investigate regional dynamics.

[12] The impulses responses within the matrix $\mathbf{A}_i(L)$ are related to the structural parameters matrix $\boldsymbol{B}_i^{-1}$ by means of the following equalities: $\mathbf{A}_i(L) = \mathbf{F}_i(L)\boldsymbol{B}_i^{-1} = \boldsymbol{B}_i^{-1} + \mathbf{F}_{i1}\boldsymbol{B}_i^{-1}L + \cdots + \mathbf{F}_{ij}\boldsymbol{B}_i^{-1}L^j = \mathbf{R}_i(L)^{-1}\boldsymbol{B}_i^{-1} = \left(\boldsymbol{I} - \sum_{j=1}^{p}\mathbf{R}_{ij}L^j\right)^{-1}\boldsymbol{B}_i^{-1}$, thus implying that $\mathbf{A}_i(0) = \boldsymbol{B}_i^{-1}$ at lag $p = 0$.

[13] The common components or time effects are defined as $\Delta\bar{\boldsymbol{z}}_t = N^{-1}\sum_{i=1}^{N}\Delta\boldsymbol{z}_{it}$, that is, the average over the N=32 Mexican states for each quarter in the sample period.

elements of the loading matrix $\Lambda_i$. Afterwards, by using the common factor representation in $\boldsymbol{\epsilon}_{it} = \Lambda_i \bar{\boldsymbol{\epsilon}}_t + \tilde{\boldsymbol{\epsilon}}_{it}$, we estimate the idiosyncratic structural shocks as the regression residual $\tilde{\boldsymbol{\epsilon}}_{it}$ and compute the state-specific idiosyncratic impulse responses.

## 6. Database and summary statistics

The structural panel VAR system consists of the 32 cross-section units corresponding to the Mexican states and a sample time spanning from 2003 to 2022 on a quarterly frequency. The state manufacturing output level $(mp_{it})$ is measured by using the Monthly Indicator of Industrial Activity by State (IMAEF by its acronym in Spanish language) which summarizes manufacturing firms behaviour by constructing a volume index. The IMAEF statistical information is publicly facilitated by the National Institute of Statistics and Geography (INEGI by its acronym in Spanish). Both types of employment, permanent $(pe_{it})$ and temporary $(te_{it})$ ones, are measured by the monthly number of employees laboring in manufacturing activities, which registers are publicly accessible at the Mexican Institute of Social Security (IMSS by its acronym in Spanish) database.[15]

In Table 1, a summary of descriptive statistics calculated on the panel data shows that the average number of permanent workers is considerably higher than its temporary counterpart. The standard deviation to mean ratio exhibits, in addition, a marked difference between the magnitudes of dispersion individually calculated for each type of employment, which suggests temporary employment is more dispersed around its state mean than permanent employment is. The output index has an average level of 101.6 and a low dispersion as the calculated ratio of standard deviation to mean equates 8.0%.

**Table 1.**
**Summary statistics**

| Statistic | mp | pe | te |
|---|---|---|---|
| Average | 101.6 | 123959 | 16497 |
| Std. Dev. | 8.0 | 131479 | 18319 |
| Std. Dev./Average | 8.0% | 106% | 111% |
| Max | 126.6 | 386694 | 80556 |
| Min | 90.6 | 6068 | 1235 |

mp denotes total manufacturing output; pe and te refers to permanent and temporary employment in manufacturing production, respectively.
**Source:** own calculations with information from INEGI and IMSS databases.

## 7. Empirical evidence

This section reports the empirical findings based on the dynamic structural responses derived from the three-variate structural panel VAR according to the practical estimation procedure that was described in the preceding methodology section.[16] Specifically, on the one hand, our estimates suggest that idiosyncratic output shocks are relevant for employment although in different magnitude. In particular, the cumulative structural responses indicate that both permanent and temporary employment would experience an augmentation, although of different proportion, in 13 states out of 32 towards the end of a

[15] Quarterly data were obtained as the average of the corresponding monthly figures.
[16] This procedure required, first, estimating the reduced form of one common panel vector autoregression and 32 composite vector autoregressions whose number of parameters and associated statistics is too large to be reported in the text, but these estimates are available upon request. The lag length was selected individually for each vector autoregression when, by inspection, at least two of the statistics provided by the Akaike information criteria, the Bayesian information criteria, and the general-to-specific approaches were generally coincident. A summary of the selected lag length for each vector autoregression is also available in Tables A1 and A2 in the Appendix.

twelve-quarter impact period.[17] Whilst, there is evidence of combined patterns in a second group comprised by 14 states, where temporary employment increases, but permanent employment decreases, and vice versa. Only in 5 states the net effect summarized in the cumulative dynamic responses manifestly suggest a decrease in total employment following a positive idiosyncratic output shock.

Regarding the interaction between both types of employment, and under the rationale that firms engage in recruiting employees on a permanent basis once the demand for their products is believed to keep stronger, an increase in the number of permanent employees may be accompanied by an augmentation or a decline in the number of temporary employees depending on whether firms aim to implement a complementation or substitution strategy between them. The estimated dynamic responses depicted in Figure 1 indicate that both types of strategies are implemented, although manufacturing firms in 21 out of 32 states would be disposed to substitute temporary by permanent employees. As might be expected, however, our estimations suggest the substitutional reallocation of temporary by permanent employment is rather heterogeneous across states. In the state of Zacatecas, for example, an unexpected positive shock on the number of permanent employees would initially induce a reduction in the number of temporary employees by 7.17% at the end of the twelve-quarter impact period.

Moreover, virtual particularities in the trajectories of the estimated dynamic responses suggests variations in the implementation of the substitution strategies. In this respect, after the initial permanent positive employment shock, manufacturing firms in the states of Aguascalientes, Guerrero and Veracruz would intensify the substitution of temporary employment, while in a second group of states, such as Coahuila, Colima, Michoacán, Puebla, Jalisco, Campeche, Oaxaca, Estado de México, Guanajuato, Hidalgo, Tlaxcala, Nuevo León and San Luis Potosí, the estimated magnitudes of the substitutive cumulated impact are smaller, ranging from -0.93 to -0.24, at the end of impact horizon. Concerning the opposite strategy, our estimations in Figure 1 suggest that manufacturing firms in 11 states would be inclined to recruit additional temporary employees; notably, the state of Tabasco, which would experience the largest complementation impact.

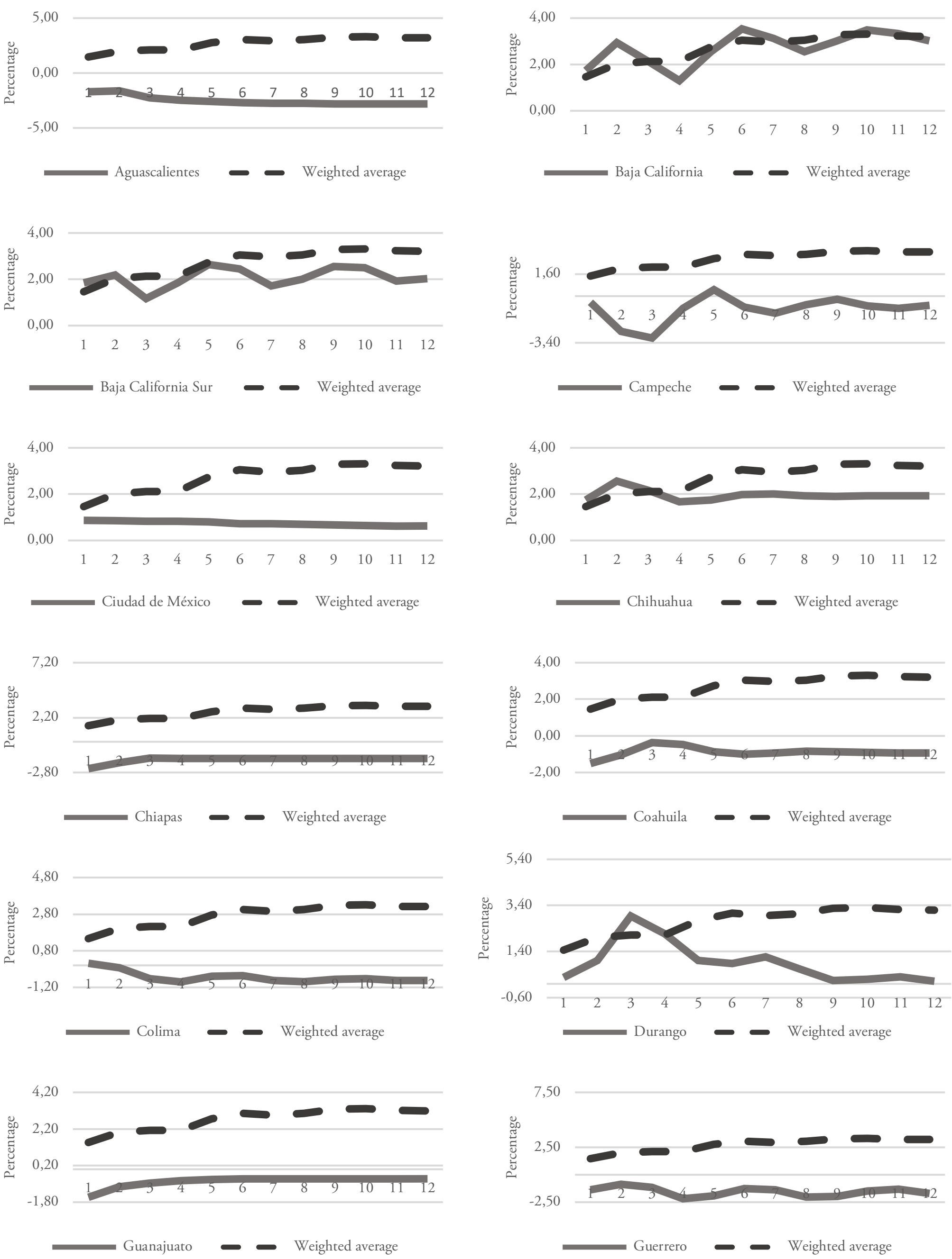
In turn, Figure 2 shows that an unexpected positive shock on the number of temporary employees would similarly induce a mix of positive and negative patterns of responses on permanent employment levels across states. Accordingly, manufacturing firms in 16 out of 32 states would be willing to recruit additional permanent employees, yet the estimated magnitudes of the impacts are rather heterogenous ranging from figures as small as 0.05% and up to 1.4% during a twelve-quarters period. In the states of Zacatecas and San Luis Potosí, for example, whose manufacturing industries contribute importantly to their total gross state production, their number of permanent employees would respectively augment by 1.4% and 1.3%. Our estimations supplementarily indicate that in 14 out of 32 states manufacturing firms located within these states would rather engage in strategies that substitute permanent by temporary employees. In this group of states, whose dynamic responses range from -0.02 to -0.95, Tamaulipas and Tlaxcala would exhibit the largest negative impact on their number of permanent employees.

Moreover, conjoining the empirical results from both Figures 1 and 2 is useful to consolidate our understanding regarding the prevailing combination of complementation and substitution strategies that manufacturing firms across states would likely implement when recruiting decisions are involved. A summary presented in Table A3 indicates that four general patterns of strategies would emerge when combining firms' recruiting decisions across states: 1) A double complementation strategy, which imply that manufacturing firms in six states would be disposed to recruit additional employees on temporary or permanent bases to accompany an initial increase in their employment level due to the corresponding positive employment shock. 2) A double substitution strategy, which consists in prescinding of temporary or permanent employees to be substituted by employees initially recruited due to the corresponding positive employment shock, would describe the behavior of manufacturing firms in ten states. 3) A strategy that combines both complementation and substitution in firms' recruiting decisions can be divided into two specific strategies according to the type of employment that is being substituted or complemented: a combination strategy that consists in rescinding temporary employees to be substituted by permanent employees or recruiting additional permanent employees in complementation of temporary ones,

[17] Because of space limitation, these cumulative impulse response functions are only available upon request.

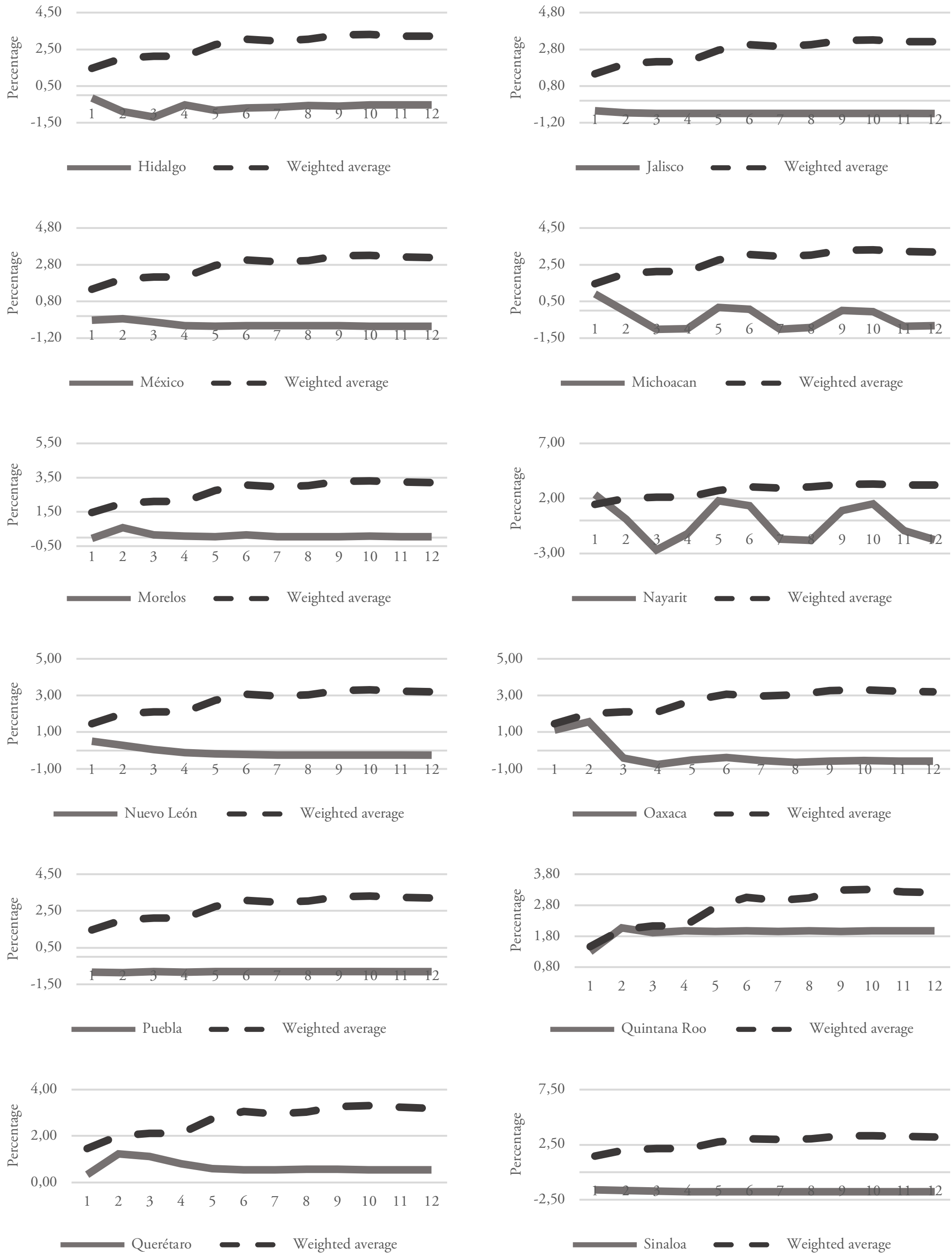
depending on the corresponding positive employment shock, would be characteristic of manufacturing firms in eleven states. The converse combination strategy was found only in five states notwithstanding.

**FIGURE 1.**
**Cumulative response estimates of temporary manufacturing employment (te) to a permanent employment (pe) idiosyncratic shock**



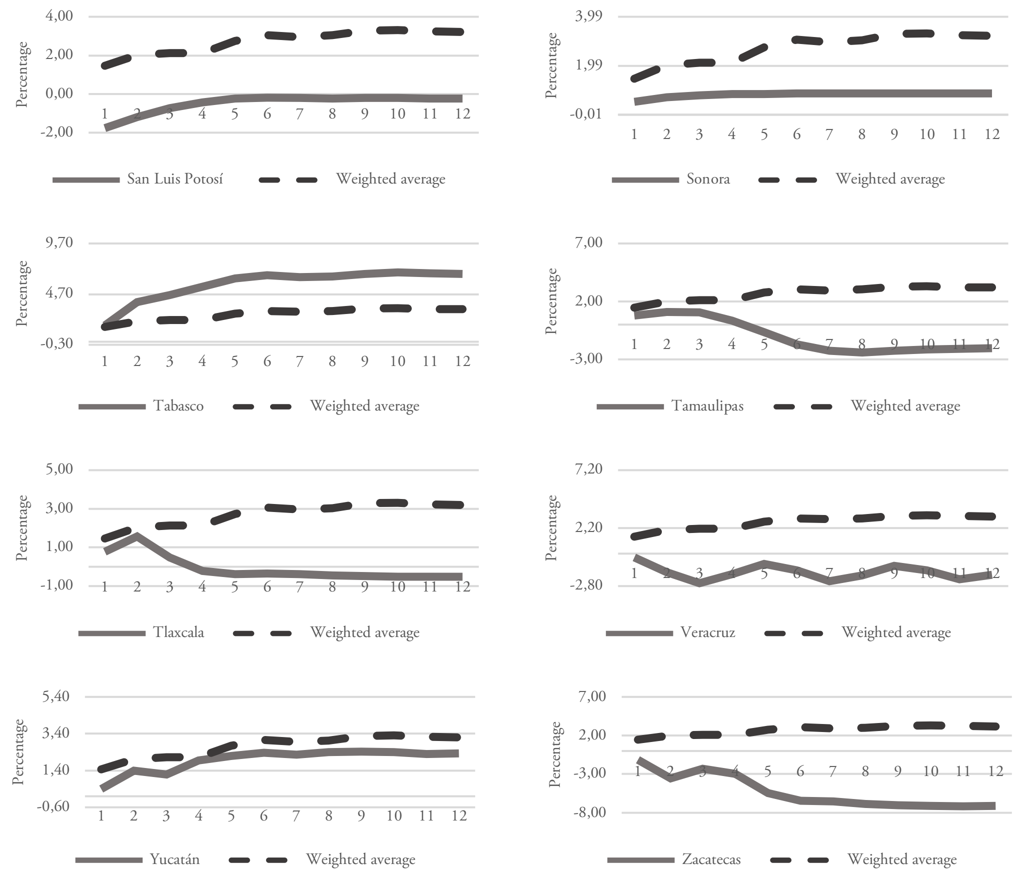

**Source:** own estimations.

FIGURE 1. CONT.
**Cumulative response estimates of temporary manufacturing employment (te) to a permanent employment (pe) idiosyncratic shock (continuation)**




**Source:** own estimations.

**Figure 1. cont.**
**Cumulative response estimates of temporary manufacturing employment (te) to a permanent employment (pe) idiosyncratic shock (continuation)**




**Source:** own estimations.

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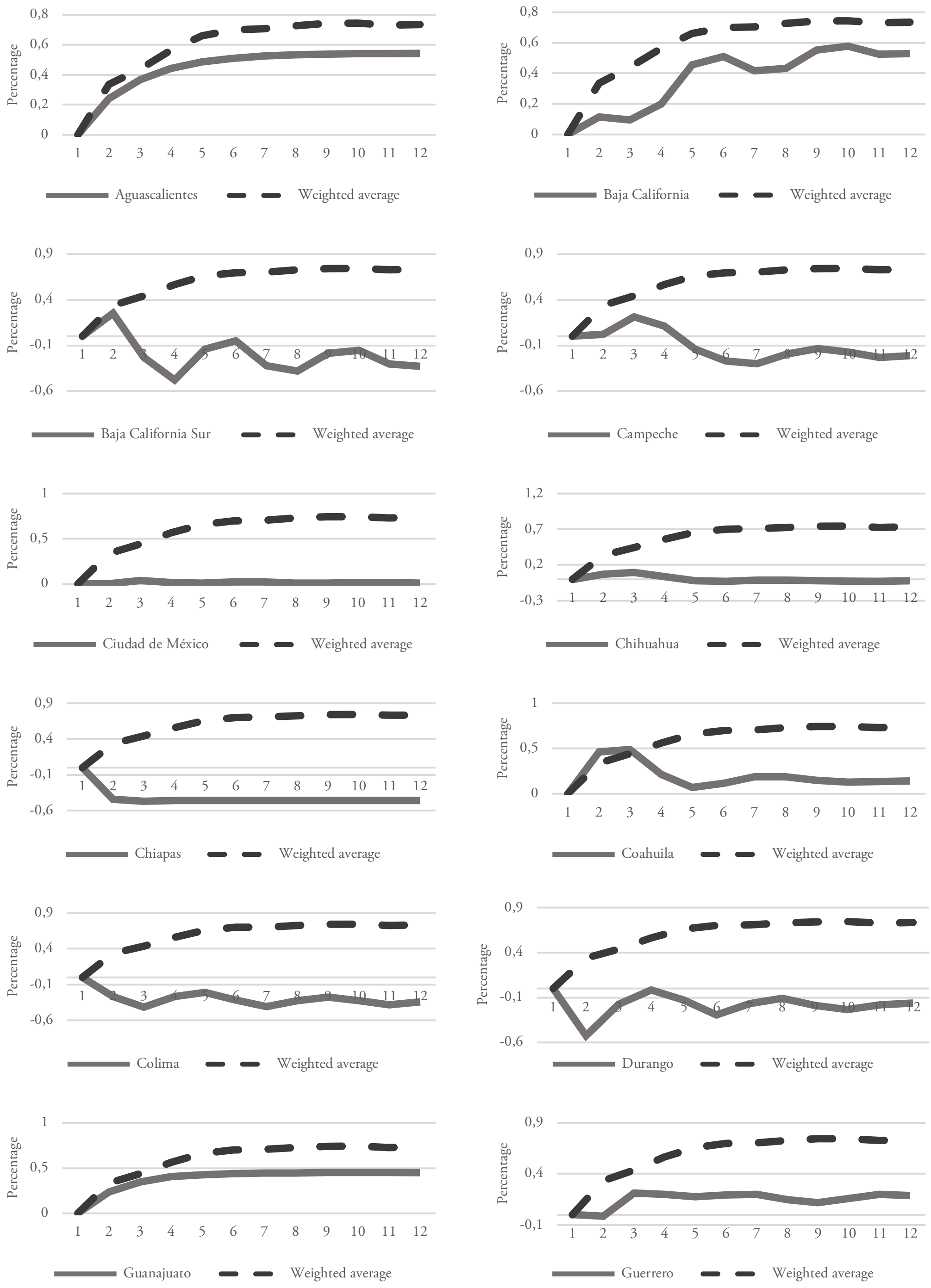
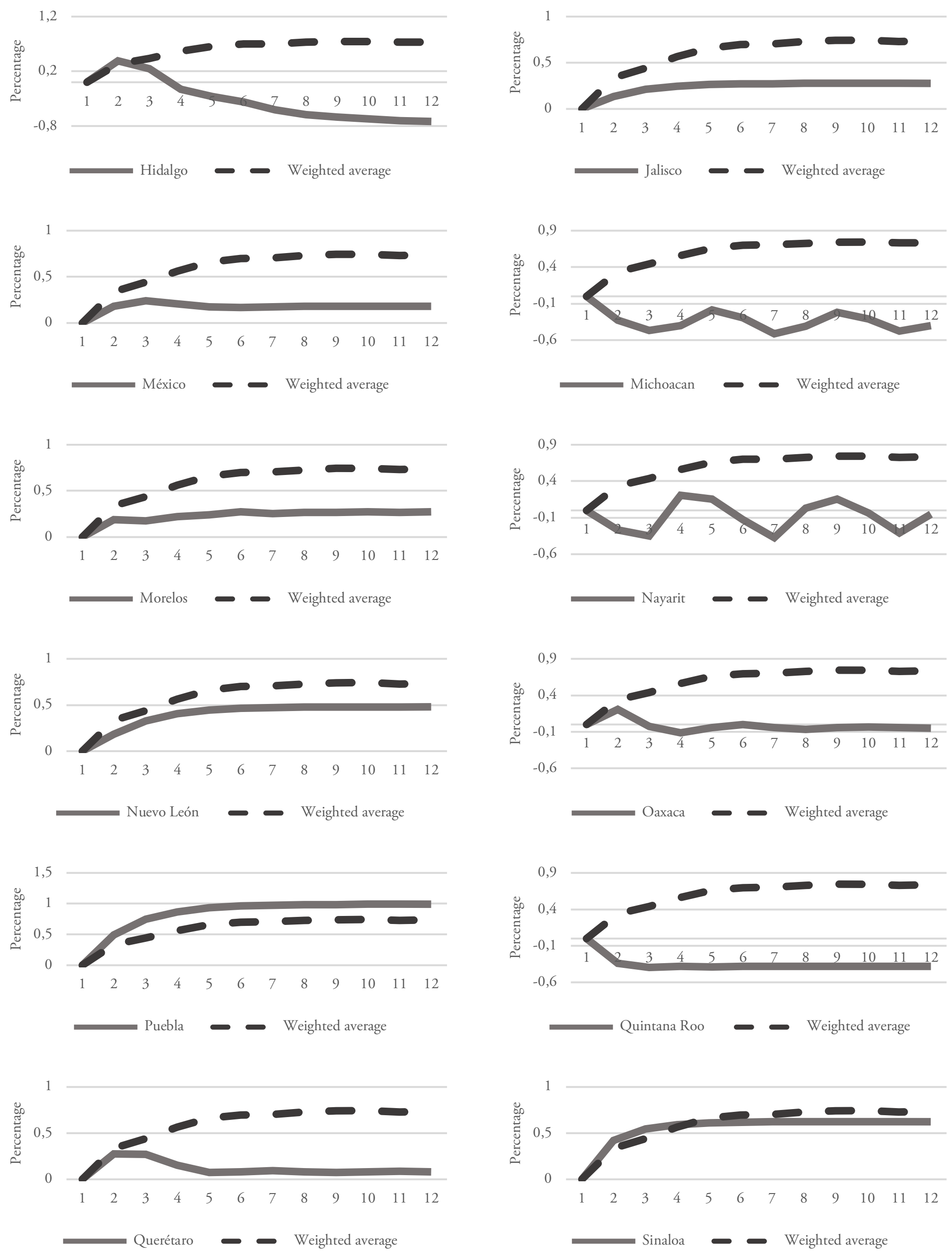
**FIGURE 2.**
**Cumulative response estimates of permanent manufacturing employment (pe) to a temporary employment (te) idiosyncratic shock**




**Source:** own estimations.

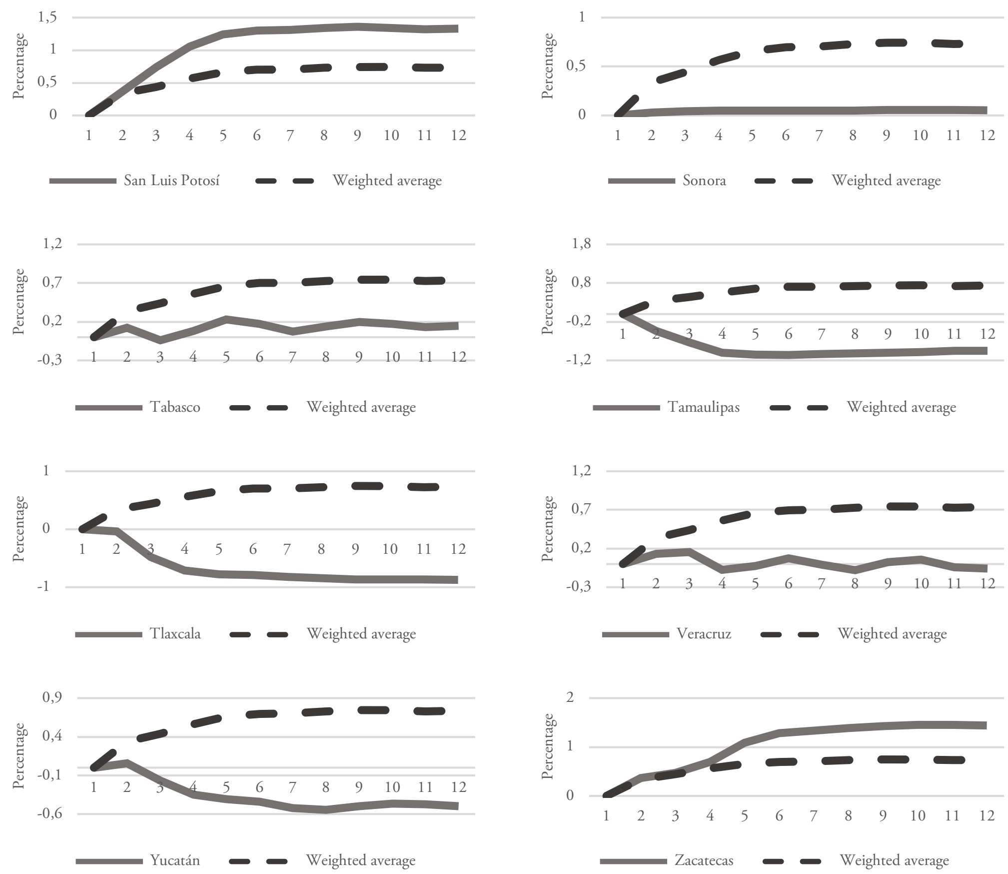
FIGURE 2. CONT.

**Cumulative response estimates of permanent manufacturing employment (pe) to a temporary employment (te) idiosyncratic shock (continuation)**




**Source:** own estimations.

**Figure 2. cont.**
**Cumulative response estimates of permanent manufacturing employment (pe) to a temporary employment (te) idiosyncratic shock (continuation)**




**Source:** own estimations.

## 8. Robustness analysis

This section reports a variety of robustness analysis performed with the intention of verifying whether our empirical findings would differ both qualitatively and quantitatively, when some modelling assumptions are modified.[18] In this regard, our first robustness test consisted in inverting the assumptions behind the imposed contemporaneous restrictions on the interaction between both types of employment, which required changing the order of the first two endogenous variables. The responses estimates based on this modelling variant are found to be rather like our initial estimates both qualitatively and quantitively, though we find it is more plausible assuming the initial set of contemporaneous restrictions under the economic rationale expressed in the text.[19]

Our second test consisted in assessing the sample sensitivity of our estimations due to the presence of events or policy variations that might have induced instability in the estimated parameters. After a careful examination of the events and policy variations that might have influenced the stability of our estimates during the sample timeframe, we regarded the implementation of the labor policy reform starting

[18] The estimated structural responses of this robustness analysis are available upon request.
[19] We are aware that another potential modification consists in assuming that demand-driven output shocks may induce contemporaneous impacts on both types of employment, however, it was discarded because this assumption does not induce any modification in the interaction between both types of employment which is central to our research.

in November 2012 as the only most likely potential source of change in the behavior of firms that consequently might have been reflected in our estimates. The procedure of our sample sensitivity test consisted thus, first, in regressing each type of employment on a dummy variable which is defined with ones from December 2012 onwards, and zeros placed in the remaining positions. Then, the residuals obtained from these regressions were used in place of the corresponding temporary and permanent employment data to deliver a new set of structural idiosyncratic impulse responses which, subsequently, were compared with the initial set of structural idiosyncratic impulse responses to assess any discrepancy between both. We found negligible differences between both sets of structural dynamic responses which attests the stability of our initial estimates to sample variation[20].

A third set of tests were performed with the intention of assessing the sensitivity of our estimates to modifications in the lag length structure of the VAR models. The specific procedure involved choosing an alternative lag length to that suggested by our adopted selection criteria only in the cases when at least one of the GTOS, BIC and AIC statistics is discrepant in pointing towards the same lag length. The procedure conducted us in the estimation of 22 dynamic responses which estimates are found to be sensitive, particularly when the alternative lag length is distantly shorter than our initial lag length structure, often showing a tendency to unsettle as the impact period goes farther which can be attributed to a lag length misspecification.

## 9. Conclusions

This study aimed to investigate the relationship between permanent and temporary employment by using statistical information for the manufacturing sector in the thirty-two Mexican states. Whereas some recent studies have paid a rising interest on the possibility that recent labor-market flexibilization policies may have led to precarious labor conditions for workers, none of them have studied whether firms within states would induce a substitution or complementation strategy between both labor dimensions. Based on a structural panel vector autoregressive system, which accommodates the heterogenous nature of state data and helps to isolate structural shocks to the labor variables, our empirical results show a heterogenous implementation of the labor market reforms across the Mexican states. Our results evince that manufacturing firms across some states would implement a double substitutive or complementation strategy between both types of employment while others would follow a combination strategy. Our estimations additionally show these responses are rather asymmetric as temporary jobs seem to be more sensitive to variations in permanent jobs than the opposite, a result that may reflect the characteristics of the corresponding labor contracts. Regarding the states' dynamic response of employment to variations in the output level, the empirical evidence encompasses the economic theory prediction that both types of employment would increase, although in some states manufacturing firms would be inclined to increase one type of employment apparently at expenses of the other. In addition, our empirical results have some practical implications from a policy perspective as they suggest the strategic rationale by which manufacturing firms across states intend to benefit from the recent labor market reforms which, in the eve of increasing concerns regarding worsening labor conditions in México, our results may prove useful to evaluate a reorganization of the incentives for promoting a complementation strategy between both types of employment that simultaneously encourage permanent posts, the quality of temporary employment and its transition to indefinite contractual labor arrangements. Further investigation needs to be done yet, focusing on the determinants and effects of both types of employment.

[20] A second sample sensitivity test was performed discarding the data from years 2020, 2021 and 2022 which allowed us to assess whether the observed initial contraction in the manufacturing sector due to the implementation of sanitary measures intended to restrain the COVID 19, and the subsequent recovery in the manufacturing activity, might have induced significant instability in the estimated parameters. After comparison, our findings suggest minor differences between both the initial and new sets of estimated dynamic responses, which supports the robustness of our estimates.

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## Appendix

**Table A1.**
**Lag length selection summary for the reduced common component vector autoregression**

| Lags | GTOS (Chi-squared test) | Lags | BIC | Lags | AIC |
|---|---|---|---|---|---|
| 0 | 0 | 0 | -13,89 | 0 | -13,98 |
| 1 | 86.87* | 1 | -14.53* | 1 | -14.88* |
| 2 | 8,87 | 2 | -14,13 | 2 | -14,72 |
| 3 | 7,54 | 3 | -13,71 | 3 | -14,51 |

**Source:** own calculations.

**TABLE A2.**
**Lag length selection summary for the reduced form composite vector autoregressions**

| State name | GTOS (Chi-squared test) | Lag | BIC | Lag | AIC | Lag | Chosen lag |
|---|---|---|---|---|---|---|---|
| Aguascalientes | 57,4633848 | 1 | -8,8244779 | 1 | -9,1756533 | 1 | 1 |
| Baja California | 38,4081588 | 3 | -10,218249 | 1 | -10,994395 | 3 | 3 |
| Baja California Sur | 67,5048303 | 3 | -8,6641213 | 3 | -9,4632815 | 3 | 3 |
| Campeche | 31,6305338 | 3 | -8,5936663 | 0 | -9,0953968 | 3 | 3 |
| Ciudad de México | 28,3605214 | 3 | -12,147302 | 3 | -12,946463 | 3 | 3 |
| Chihuahua | 19,4647628 | 2 | -9,8703139 | 1 | -10,221489 | 1 | 2 |
| Chiapas | 20,9398338 | 1 | -9,139957 | 0 | -9,2522317 | 1 | 1 |
| Coahuila | 36,8816548 | 2 | -9,56618 | 1 | -10,128044 | 2 | 2 |
| Colima | 71,8164898 | 3 | -9,1335095 | 3 | -9,9326697 | 3 | 3 |
| Durango | 26,5088837 | 3 | -9,9972654 | 0 | -10,322405 | 3 | 3 |
| Guanajuato | 86,7990924 | 1 | -11,287349 | 1 | -11,638524 | 1 | 1 |
| Guerrero | 40,5153607 | 3 | -9,8938018 | 1 | -10,529714 | 3 | 3 |
| Hidalgo | 17,0398279 | 3 | -9,8282632 | 1 | -10,179439 | 1 | 3 |
| Jalisco | 27,8342527 | 1 | -12,697011 | 0 | -12,901211 | 1 | 1 |
| México | 18,3612203 | 2 | -12,443928 | 1 | -12,795104 | 1 | 2 |
| Michoacan | 26,5653479 | 3 | -9,2685434 | 2 | -9,9038097 | 3 | 3 |
| Morelos | 42,3898054 | 2 | -11,750651 | 0 | -12,137222 | 2 | 2 |
| Nayarit | 103,855792 | 3 | -7,0231924 | 3 | -7,8223526 | 3 | 3 |
| Nuevo León | 67,8081112 | 1 | -12,266871 | 1 | -12,618046 | 1 | 1 |
| Oaxaca | 30,3259532 | 2 | -8,6573325 | 0 | -8,7684691 | 2 | 2 |
| Puebla | 56,3865996 | 1 | -9,3308901 | 1 | -9,6820655 | 1 | 1 |
| Quintana Roo | 21,4577657 | 1 | -6,847624 | 0 | -6,9668044 | 1 | 1 |
| Querétaro | 64,3130841 | 2 | -10,833988 | 2 | -11,422195 | 2 | 2 |
| Sinaloa | 36,3871044 | 1 | -9,8277712 | 0 | -10,146009 | 1 | 1 |
| San Luis Potosí | 30,6518611 | 3 | -11,417164 | 1 | -11,980205 | 3 | 3 |
| Sonora | 37,4245321 | 1 | -9,3314012 | 0 | -9,6634719 | 1 | 1 |
| Tabasco | 23,6756712 | 3 | -8,7818205 | 0 | -9,1280151 | 3 | 3 |
| Tamaulipas | 34,7002856 | 3 | -11,561094 | 1 | -12,031816 | 3 | 3 |
| Tlaxcala | 17,08232 | 2 | -9,2721992 | 1 | -9,6233747 | 1 | 2 |
| Veracruz | 21,3994254 | 3 | -10,973775 | 2 | -11,561982 | 2 | 3 |
| Yucatán | 42,240229 | 3 | -10,533797 | 1 | -10,950371 | 3 | 3 |
| Zacatecas | 28,1113818 | 3 | -6,7161464 | 0 | -7,1293429 | 3 | 3 |

**Source:** own calculations.

**Table A3.**
**Summary of the cumulated permanent and temporary employment responses to their respective employment shocks and associated complementation and substitution strategies across the Mexican states**

| State | Resp. of temporary employment | Strategy | Resp. of permanent employment | Strategy |
|---|---|---|---|---|
| Tabasco | 6,7 | Complementation | 0,15 | Complementation |
| Baja California | 3,03 | Complementation | 0,53 | Complementation |
| Sonora | 0,86 | Complementation | 0,05 | Complementation |
| Ciudad de México | 0,63 | Complementation | 0,01 | Complementation |
| Querétaro | 0,54 | Complementation | 0,08 | Complementation |
| Morelos | 0,06 | Complementation | 0,27 | Complementation |
| Yucatán | 2,34 | Complementation | -0,5 | Substitution |
| Baja California Sur | 2,03 | Complementation | -0,33 | Substitution |
| Quintana Roo | 1,96 | Complementation | -0,38 | Substitution |
| Chihuahua | 1,93 | Complementation | -0,02 | Substitution |
| Durango | 0,11 | Complementation | -0,16 | Substitution |
| Tlaxcala | -0,52 | Substitution | -0,87 | Substitution |
| Hidalgo | -0,52 | Substitution | -0,72 | Substitution |
| Oaxaca | -0,59 | Substitution | -0,05 | Substitution |
| Campeche | -0,69 | Substitution | -0,21 | Substitution |
| Michoacan | -0,81 | Substitution | -0,4 | Substitution |
| Colima | -0,83 | Substitution | -0,34 | Substitution |
| Chiapas | -1,55 | Substitution | -0,46 | Substitution |
| Nayarit | -1,74 | Substitution | -0,05 | Substitution |
| Veracruz | -1,85 | Substitution | -0,06 | Substitution |
| Tamaulipas | -2,03 | Substitution | -0,95 | Substitution |
| San Luis Potosí | -0,24 | Substitution | 1,33 | Complementation |
| Nuevo León | -0,25 | Substitution | 0,48 | Complementation |
| Guanajuato | -0,52 | Substitution | 0,45 | Complementation |
| México | -0,54 | Substitution | 0,18 | Complementation |
| Jalisco | -0,7 | Substitution | 0,28 | Complementation |
| Puebla | -0,81 | Substitution | 0,99 | Complementation |
| Coahuila | -0,93 | Substitution | 0,14 | Complementation |
| Guerrero | -1,72 | Substitution | 0,19 | Complementation |
| Sinaloa | -1,77 | Substitution | 0,62 | Complementation |
| Aguascalientes | -2,81 | Substitution | 0,54 | Complementation |
| Zacatecas | -7,14 | Substitution | 1,44 | Complementation |

**Source:** own elaboration with information from Figures 1 and 2.

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Articles

# Mujeres y techo de cristal: diferencias regionales en España a través de un indicador sintético

*Lidia de Castro Romero*, Víctor Martín Barroso**, Rosa Santero Sánchez****

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## Resumen:

El objetivo del presente artículo es proponer y elaborar un índice de techo de cristal a nivel regional para España, utilizando como punto de partida el índice elaborado por la revista The Economist a partir de 2014 para medir el techo de cristal en más de veinte países de la OCDE. El indicador propuesto consiste en un índice sintético cuyo principal objetivo es servir de herramienta para comparar la presencia de techo de cristal y su evolución en el tiempo entre las distintas comunidades autónomas. De esta forma, el índice puede facilitar el diseño de políticas específicas para combatir el fenómeno.

**Palabras clave:** Techo de cristal; igualdad de género; empoderamiento; regiones; índice sintético.
**Clasificación JEL:** C38; J16; J71; R59.

## Women and the glass ceiling index: regional differences in Spain through a synthetic indicator

## Abstract:

The aim of this article is to propose and build a glass-ceiling index at the regional level in Spain, using as a starting point the glass-ceiling index proposed by The Economist from 2014 onwards which measures the role and influence of women in the workforce across the OECD countries. We propose a synthetic index whose main objective is to serve as a tool to compare the presence of a glass-ceiling and its evolution over time between the different autonomous communities. The index can facilitate the design of specific policies to combat the phenomenon.

**Keywords:** Glass ceiling; gender equality; empowerment; regions; synthetic index.
**JEL Classification:** C38; J16; J71; R59.

## 1. Introducción

La igualdad entre hombres y mujeres no solo es un derecho fundamental de las personas, sino que es uno de los ejes fundamentales para la transformación de nuestra sociedad hacia la sostenibilidad (Bericat, 2012). La desigualdad y discriminación de género es una de las formas más profundas de discriminación en la

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sociedad actual (Agarwal, 2018) y se encuentra en distintos ámbitos, como el educativo, laboral o político, por lo que sigue siendo necesario analizar estas situaciones para diseñar políticas que permitan avanzar hacia una sociedad más igualitaria.

Para avanzar en el reconocimiento de estas desigualdades es necesario contar con indicadores cuantitativos y cualitativos que muestren las diferentes realidades entre hombres y mujeres, y que incorporen una perspectiva de género, que permita cuestionar y valorar aspectos fundamentales para explicar esas diferencias. A estos indicadores se les denomina "indicadores de género" y son esenciales para promover el desarrollo y analizar el avance de los territorios en la reducción de las brechas de género (Moise-Titei, 2014).

Asegurar la participación plena y efectiva de las mujeres y la igualdad de oportunidades de liderazgo a todos los niveles decisorios en la vida política, económica y pública es una de las metas de los Objetivos de Desarrollo Sostenible (Naciones Unidas, s.f.). Una de las dificultades que tienen las mujeres en el desarrollo de su empoderamiento y su acceso a puestos de decisión es lo que se conoce como el fenómeno "techo de cristal", una barrera que resulta un fuerte impedimento para que las mujeres puedan moverse dentro de las jerarquías corporativas (Morrison et al., 1987) y accedan a las más altas posiciones de un orden social (Palacios Gómez, 2020; Gallego Morón, 2017). Por ejemplo, en la Unión Europea en 2021 el número de mujeres en los consejos de administración de las empresas cotizadas ha alcanzado el 32,3%, mientras que solo el 8,8% ocupan la presidencia (European Institute for Gender Equality [EIGE], s.f.).

Este fenómeno tiene su origen en la cultura estereotipada de género predominante, un constructo social que otorga un rol distinto a mujeres y a hombres, construyendo unas demandas particulares y una jerarquía social en todos los ámbitos de la vida. En este sentido, son los hombres quienes tradicionalmente han ocupado el espacio público y, por tanto, los puestos de poder (Viata y Mumo, 2019).

Romper el techo de cristal requiere reconocimiento y conocimiento. En primer lugar, se debe reconocer que existe y, después, explorar sus causas y consecuencias, para poder diseñar acciones y políticas adecuadas que acaben con este fenómeno. La literatura existente reconoce que los mecanismos en el comportamiento y las creencias colectivas que moldean la sociedad actúan en las decisiones laborales y en los procesos de selección sustentando y manteniendo un techo de cristal que ni siquiera las mujeres perciben (Mateos de Cabo et al., 2011).

En 2014, la revista The Economist comenzó a elaborar un índice para medir el techo de cristal en más de veinte países de la Organización para la Cooperación y el Desarrollo Económicos (OCDE), incluido España. Este índice incluye entre sus ámbitos algunas variables que no se adecúan a la sociedad española (como haber realizado un examen GMAT[1]) y, por el contrario, no se tiene en cuenta otras que pueden ser relevantes en nuestra sociedad, como la conciliación (de Miguel, 2015). Por ello, aunque la iniciativa de medir el techo de cristal nos parece muy relevante, cuestionamos la forma de construir ese índice y la representatividad de las variables asociadas a nuestro país. Además, la descentralización de políticas en España y la delegación de competencias en las comunidades autónomas, tienen como consecuencia diferencias regionales que deben tenerse en cuenta de cara a conocer el techo de cristal, sus causas específicas y las posibles actuaciones que permitan mejorar la presencia de mujeres en los puestos de decisión.

Así, nuestro objetivo es crear un Índice Regional de Techo de Cristal (IRTC), un indicador sintético a nivel regional en España (NUTS2), susceptible de ser calculado anualmente, que sirva de herramienta comparativa y fomente, dadas las competencias de las comunidades autónomas, el conocimiento del fenómeno y el diseño de políticas específicas para su eliminación. Este objetivo se adecúa a las recomendaciones de política nacional en dos aspectos: la Ley Orgánica 3/2007 para la igualdad efectiva entre mujeres y hombres (artículo 20.b) insta a los poderes públicos a "establecer nuevos indicadores que posibiliten un mejor conocimiento de las diferencias en los valores, roles, situaciones, condiciones, aspiraciones y necesidades de mujeres y hombres, su manifestación e interacción" y, el informe del Gobierno de España (2019) por el 25º aniversario de la Conferencia de Beijing reconoce que "a pesar de

[1] Siglas de "Graduate Management Admission", un examen que mide la aptitud para cursar másters tipo MBA.

un aumento de la presencia de las mujeres en el ámbito económico, es sin embargo necesario avanzar hacia el equilibrio en los nombramientos en puestos de toma de decisiones a todos los niveles".

El trabajo se estructura de la siguiente manera. En el apartado 2 se revisa la literatura previa existente, tanto la relacionada con el concepto teórico del techo de cristal como la relacionada con la aproximación empírica del mismo. En el apartado 3 se describe la metodología utilizada para la elaboración del IRTC. En el apartado 4 se analizan los resultados del índice calculado para las comunidades autónomas y se mide la convergencia regional del mismo. Por último, en el apartado 5 se presentan las principales conclusiones y recomendaciones de política.

## 2. Revisión de la literatura

### 2.1. Aproximación teórica al fenómeno del techo de cristal

El techo de cristal es una metáfora para identificar barreras invisibles e informales que impiden que las mujeres obtengan promociones, aumentos de sueldo y otras oportunidades de acceso a puestos de decisión. Inicialmente, el término se utilizó ligado a organizaciones económicas, pero luego se ha ido extendiendo a otras áreas, como la política o la negociación colectiva (Viata y Mumo, 2019). En el ámbito económico existe una infrarrepresentación de mujeres en puestos de responsabilidad, disminuyendo su presencia a medida que mejora la categoría laboral, especialmente en los puestos de dirección tanto en organizaciones públicas como privadas. Para alcanzar mayores niveles de responsabilidad es necesario tener la formación y experiencia adecuadas al puesto, y estas se alcanzan a través de la educación y la trayectoria profesional de las personas.

En cuanto a la trayectoria profesional, hasta hace algunas décadas, las mujeres no se habían incorporado de forma masiva al mercado laboral. Sin embargo, en la actualidad, el perfil frecuente de ejecutivo según WeEqual (2020) y de acuerdo con datos del INE, es de un hombre de unos 50 a 59 años. Esto supone que hayan nacido en la década de los 70 y se hayan incorporado al mundo laboral a partir de la década de los 80, en la que se dio la incorporación masiva de la mujer al mundo laboral (Millán-Vázquez de la Torre et al., 2015). En consecuencia, en la actualidad las trayectorias profesionales deberían ser semejantes, dado que, los niveles de educación son similares, o incluso superiores, en las mujeres (Carrasco-Santos et al., 2020). La masculinización de los puestos de responsabilidad, por tanto, vendría justificada por otras causas, como la amplia disponibilidad horaria o la asunción de responsabilidades de cuidados, como exponemos más adelante.

La revisión de literatura separa las causas del techo de cristal en variables externas, que se sustentan en la existencia de conductas discriminatorias en las organizaciones, y en variables internas, referidas a las autolimitaciones profesionales de las mujeres por la identidad que han construido en el sistema patriarcal (Albert López-Ibor et al., 2008). No obstante, es importante considerar que ambos tipos de variables no actúan de forma aislada, sino que interactúan entre sí formando un entramado que imposibilita a las mujeres romper con el techo de cristal (Barberá et al., 2003).

Las explicaciones centradas en las variables externas recurren a la existencia de estereotipos y roles de género, que actúan como socializadores creando una identidad y subjetividad en el sexo femenino. Las atribuciones formadas en este proceso marcan características de personalidad y motivación de logro, intereses vocacionales y profesionales, estilos de liderazgo, centralidad y compromiso laboral, y conflictos relacionados con la maternidad (Barberá et al., 2003).

En los conflictos con la maternidad, los estereotipos hacen que asumamos que las mujeres son las responsables de los cuidados por la extendida asunción de la inclinación natural hacia ello, cuyo origen está en la construcción cultural, situando las mayores responsabilidades familiares de las mujeres como un factor determinante en su carrera profesional como directivas (Cuadrado y Morales, 2007). Desde el punto de vista económico y organizacional, la maternidad se ha tratado como una enfermedad o invalidez que dificulta el desarrollo profesional, al tener que compaginar esta tarea con una atención completa a la carrera laboral que permita el ascenso a puestos de poder. Sin embargo, la conciliación es aún una utopía y cuando las cargas familiares presionan, la solución suele ser cambiar la jornada laboral a tiempo parcial o coger excedencias, lo que disminuye las probabilidades de ascenso en la carrera profesional y, por tanto, alcanzar puestos de responsabilidad.

Ligado al techo de cristal también está asociada la brecha salarial de género. La brecha salarial no explicada por factores observados que podrían explicar las diferencias, como las habilidades y la experiencia, en España apenas ha experimentado cambios importantes en la última década, pasando del 9,1% en 2010 al 10,9% en 2018 (Leythienne y Pérez-Julián, 2021). Estas brechas salariales se amplían en los puestos de mayor responsabilidad, alcanzando el 19% en los puestos de dirección y gerencia. Parece evidente que ambos diferenciales, jerárquico y retributivo, estarían relacionados, puesto que las posiciones jerárquicas más elevadas suelen estar mejor retribuidas (Palacios Gómez, 2020). Asimismo, si las mujeres no son reconocidas en trabajos y posiciones semejantes a sus compañeros hombres, es de esperar que se dificulte su acceso a los puestos laborales que ostentan mayor poder social.

## 2.2. Aproximación empírica al techo de cristal a través de indicadores de género

El techo de cristal se ha analizado de forma empírica a través de diferentes indicadores, como el grado de feminización en puestos de dirección, la brecha salarial de género o el índice de disimilaridad en categorías profesionales elevadas en diferentes sectores. En estos casos, los indicadores se construyen a partir de una única variable, pero también se encuentran indicadores sintéticos multivariables, que unen varias características, como el Glass Ceiling Index creado por The Economist (de Miguel, 2015). En la actualidad, este tipo de indicadores específicos de techo de cristal son prácticamente inexistentes. Sin embargo, sí hay un amplio desarrollo de indicadores sintéticos de brecha o desigualdad de género más amplios, en los que se incluyen algunas de las variables que son de interés para conocer el techo de cristal. A continuación, se recogen en los siguientes apartados una revisión de estos indicadores, que nos sirven como base para la elaboración de nuestra propuesta de IRTC.

### 2.2.1. Indicadores de desigualdad de género a nivel internacional

Uno de los primeros índices de desigualdad de género calculado a nivel internacional fue el Gender Equality (Sugarman y Straus, 1988), pero no fue hasta 1995 con la Declaración de Beijing cuando se potenció la construcción de este tipo de indicadores. El Programa de las Naciones Unidas para el Desarrollo (PNUD) comenzó a elaborar en ese mismo año dos índices de género: (i) el Gender Development Index (GDI) (United Nations Development Programme [UNDP], s.f.a) con el objetivo de analizar las desigualdades de género con relación al Human Development Index que ellos mismos elaboran para más de 160 países y (ii) el Gender Empowerment Measure (GEM) (UNDP, 2009), un índice sintético que medía el empoderamiento femenino según su representación en puestos de poder y su salario. Este último se elaboró hasta 2009, cuando fue sustituido por el Gender Inequality Index (GII) (UNDP, s.f.b) en el que, además de contemplar la representación de mujeres en puestos de poder y su participación en el mercado laboral, incluye temas de salud.

Otros organismos internacionales que han desarrollado índices de brecha de género son el Foro Económico Mundial, el Instituto Europeo de la Igualdad de Género (EIGE), la OCDE, o la Agencia de los Estados Unidos para el Desarrollo Internacional (USAID). En la Tabla 1 se resume la información más relevante de estos indicadores, incluyendo la valoración de cada indicador para España y su posición relativa frente al conjunto de países para los que se realiza.

**Tabla 1.**
**Comparativa Índices de Género Internacionales**

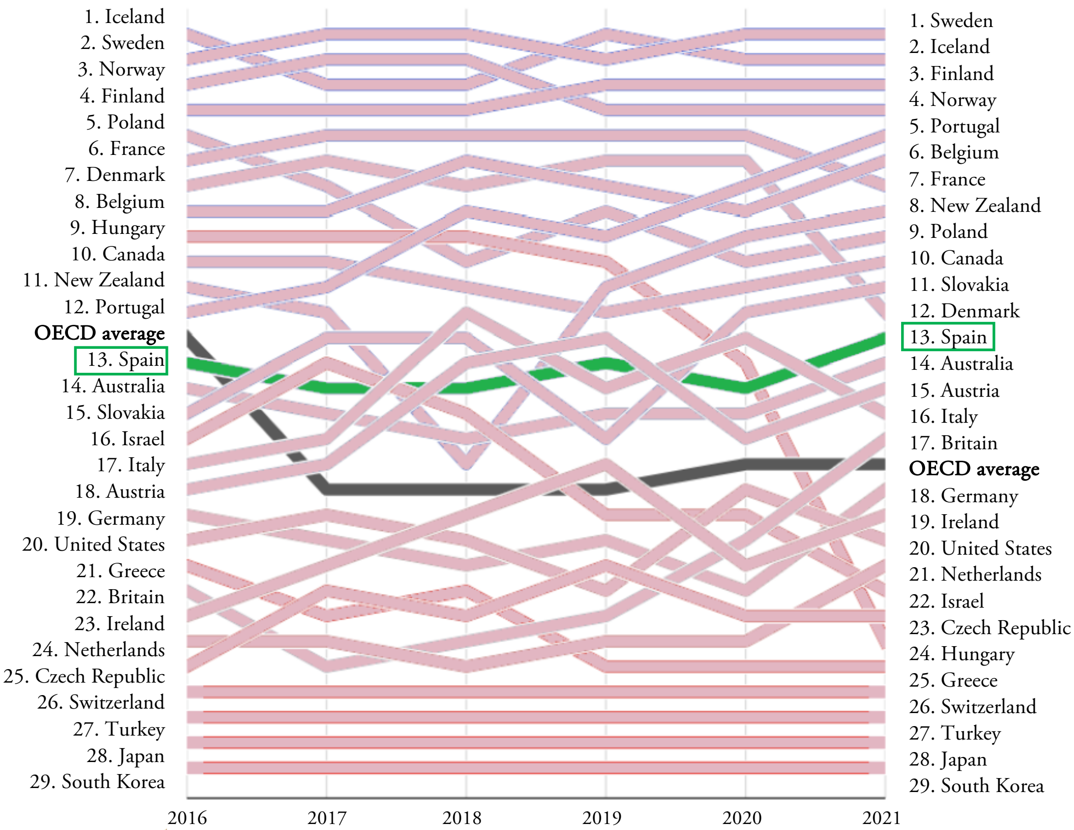
| Índice | Desarrollado | Objetivo | Periodo | Bases de datos | ESPAÑA Valor | ESPAÑA Posición |
|---|---|---|---|---|---|---|
| **Gender Development Index (GDI)** | PNUD | Ajustar el Índice de Desarrollo Humano con las desigualdades entre hombres y mujeres. | Anual desde 1995 | UN, World Bank Statistics | 0,986[2] | 25/189 |
| **Gender Empowerment Measure (GEM)** | PNUD | Medir el empoderamiento relativo de mujeres y hombres en las esferas de actividad política y económica. | Anual 1995-2009 | UN, ILO, Inter-Parliamentary Union, World Bank | 0,835[3] | 11/109 |
| **Gender Inequality Index (GII)** | PNUD | Analizar el coste de desarrollo humano originada por la desigualdad entre logros femeninos y masculinos. | Anual desde 2010 | WHO; UNICEF; UNFPA; WB; UN; UNDESA; IPU; UNESCO; ILO | 0,07[4] | 16/162 |
| **Global Gender Gap Index (GGI)**[5] | Foro Económico Mundial | Evaluación de las desigualdades globales de género en criterios económicos, políticos, educativos y de salud. | 2006 y anual desde 2010 | ILO, WEF, UNESCO, WB, WHO, Inter- Parliamentary union | 0,788[6] | 14/156 |
| **Gender Equality Index (GEI)**[7] | EIGE | Medir el progreso de la igualdad de género en la UE. | 2013, 2015, 2017, 2019, 2020 | Eurostat, Eurofound, EIGE | 72[8] | 8/28 |
| **Social Institution and Gender Index (SIGI)**[9] | OCDE | Analizar cómo las instituciones sociales discriminatorias causan desigualdades en mujeres y niñas. | 2009, 2012, 2014, 2019 | Gender, Institutions and Development Database (GID-DB) | 0,14[10] | 12/120 |
| **Women´s Economic Empowerment and Equality Dashboard (WE3)**[11] | USAID | Evalúar la inclusión de mujeres en la economía, mostrando el nivel de empoderamiento económico, social y político. | Anual desde 2018 | WB, V-Dem, UNESCO, OECD (SIGI), TIP, UN, UN SDG, WHO, UNAIDS | 1,76[12] | /180 |
| **Glass Ceiling Index** | The Economist | Medir la posibilidad de que las mujeres accedan a puestos de responsabilidad y toma de decisiones tanto en el ámbito público como el privado. | Anual desde 2014 | EIGE, Eurostat, MSCI ESG, GMAC, ILO, Inter-Parliamentary Union, OECD, National Surces | 63,6[13] | 15/29 |

**Fuente:** elaboración propia

[2] Valoración posible entre 0-1 siendo 1 la total igualdad. Dato del índice calculado para 2019 (UNDP, 2020).
[3] Valoración posible entre 0-1 siendo 1 la total igualdad. Dato del índice calculado para 2009 (UNDP, 2009).
[4] Valoración posible entre 0-1 siendo 0 la total igualdad. Dato del índice calculado para 2019 (UNDP, 2020).
[5] (World Economic Forum [WEF], 2021)
[6] Valoración posible entre 0-1 siendo 1 la total igualdad. Dato del índice calculado para 2021 (WEF, 2021).
[7] (EIGE, 2020)
[8] Valoración posible entre 0-100 siendo 100 la total igualdad. Dato del índice calculado para 2020 (EIGE, 2020).
[9] (Organization for Economic Cooperation and Development [OECD], 2019)
[10] Valoración posible entre 0-1 siendo 0 la total igualdad. Dato del índice calculado para 2019 (OECD, 2019).
[11] (United States Agency for International Development [USAID], s.f.)
[12] Valoración posible entre 0-5 siendo 5 la total igualdad Puntuación de la dimensión "Decision Making" (USAID, 2019).
[13]Valoración posible entre 0-100 siendo 100 la total igualdad (The Economist, 2021)

Todos estos índices, a excepción del Glass Ceiling Index, miden la desigualdad desde distintas aproximaciones, pero siempre con un foco global, incluyendo distintas dimensiones entre las que se encuentra la relativa al empoderamiento. Sin embargo, la desigualdad en el poder puede analizarse más detallada y profundamente para obtener información sobre cómo opera en un ámbito tan concreto. Así lo entendió The Economist, dada la creación de su Glass Ceiling Index, cuyo cálculo ha situado a España cada año a partir de 2017 en una posición superior a la media de la OCDE, y que se toma como referencia para la elaboración del índice propuesto. La apreciación del descenso de la media de los países de la OCDE analizados en este índice proviene de la disminución del porcentaje de mujeres en puestos de dirección entre el índice de 2016 y 2018, pasando del 37,1% al 31,8%, que ha sido provocado por los países que encabezan el ranking. Así como por la disminución del porcentaje de mujeres en los consejos de administración para el mismo periodo, que pasa del 31,9% al 22,9%, como consecuencia de la disminución de mujeres en los países con posiciones centrales en el ranking (The Economist, 2023).

**Gráfico 1.**
**Evolución de la clasificación del Glass Ceiling Index de The Economist.**




**Fuente:** The Economist's glass-ceiling index (The Economist, 2023).

## 2.2.2. Indicadores de desigualdad de género a nivel regional en España

Parece evidente que pueden existir diferencias regionales, puesto que la desigualdad es indiscutible en todas partes, pero su naturaleza y grado son heterogéneos (Dilli et al., 2019). A nivel nacional, también se han desarrollado indicadores para examinar de forma más específica la realidad de las desigualdades de género por comunidades autónomas. Entre ellos hemos encontrado: (i) el Índice de Desigualdad de Género (Bericat Alastuey y Sánchez Bermejo, 2008) que mide la desigualdad de género en las comunidades autónomas; (ii) el Índice de Equidad de Género Modificado (Fernández-Sáez et al., 2016) que visibiliza la evolución de la inequidad de género en las comunidades autónomas españolas desde 2006 hasta 2014; (iii) el Gender Equality Index of the Autonomous Communities of Spain (Gil-Lafuente et al., 2019) que establece un diagnóstico de la desigualdad en las comunidades autónomas para posteriormente analizar cómo influye en la economía regional; y (iv) el Índice de Igualdad de Género de Cantabria (Instituto Cántabro de Estadística, s.f.) que refleja la brecha de género en la realidad socioeconómica de Cantabria comparando este valor con el calculado para España.

En la tabla 2 se resume la información más relevante de estos indicadores, incluyendo las dimensiones y variables, así como los valores medios para España y la identificación de las regiones más y menos favorables a las brechas de género en cada uno de los casos.

**TABLA 2.**
**Comparativa Índices de Género Regionales en España**

| ÍNDICE | DIMENSIONES (Y VARIABLES) | INDICADORES (dimensión poder/empoderamiento) | RESULTADOS |
|---|---|---|---|
| **Índice de Desigualdad de Género** | 1. Educativa<br>2. Laboral<br>**3. Poder**<br>a. Político<br>b. Gerencial<br>c. Social | • Concejalas y alcaldesas.<br>• Parlamentarias.<br>• Juezas y magistradas.<br>• Mujeres ocupadas en la dirección general/presidencia de empresas de 10 o más trabajadores.<br>• Mujeres empresarias en la dirección general/presidencia de empresas de 10 o más trabajadores.<br>• Directoras de administraciones públicas.<br>• Mujeres en ocupaciones de prestigio[14]. | **2001-2006**<br>(=0 igualdad; >0 inequidad a favor de hombres.<br>Media estatal: 0,824<br>Más desfavorable: Murcia: 1,034<br>Más favorables: País Vasco: 0,651 |
| **Índice de Equidad de Género Modificado** | 1. Actividad económica<br>2. Educación<br>**3. Empoderamiento** | • Mujeres con cargos técnicos y profesionales<br>• Mujeres con escaño en el Parlamento de cada comunidad.<br>• Mujeres consejeras en el gobierno de cada comunidad. | **2014**<br>(=0 igualdad; <0 inequidad a favor de hombres)<br>Media estatal: -0,071<br>Más desfavorable: Galicia: -0,3122<br>Más favorable: Canarias: 0,1053 |

[14] Abogados y fiscales, escritores y artistas de la creación, médicos y odontólogos, militares, profesores de universidad y gerentes de empresas con menos de 10 asalariados.

TABLA 2. CONT.

**Comparativa Índices de Género Regionales en España**

| ÍNDICE | DIMENSIONES (Y VARIABLES) | INDICADORES (dimensión poder/empoderamiento) | RESULTADOS |
|---|---|---|---|
| **Gender Equality Index of the Autonomous Communities of Spain** | 1. Educación<br>2. Mercado laboral<br>3. Condiciones sociales<br>**4. Empoderamiento** | • Presidentas y concejalas en gobiernos autonómicos.<br>• Diputadas autonómicas.<br>• Alcaldesas.<br>• Profesoras e investigadoras en las universidades.<br>• Afiliadas a la seguridad social como directoras y gerentes.<br>• Deportistas con licencia federativa estatal o autonómica homologada. | **2016**<br>(=0 igualdad; <0 inequidad a favor de hombres)<br>Media estatal: -0,3558<br>Más desfavorable: Cantabria: -0,4597<br>Más favorable: Murcia: -0,2640 |
| **Índice de Igualdad de Género de Cantabria** | 1. Educación<br>2. Trabajo productivo<br>3. Ingresos económicos<br>**4. Poder y toma de decisiones**<br>5. Salud<br>6. Trabajo reproductivo | • Participación en las concejalías<br>• Participación en los parlamentos autonómicos<br>• Mujeres elegidas para el cargo de diputada o senadora<br>• Mujeres en puestos directivos | **2019**<br>(=0 igualdad; <0 inequidad a favor de hombres)<br>España: 0,6553<br>Cantabria: 0,6371 |

**Fuente:** Elaboración propia.

## 3. Metodología y datos

La aproximación empírica al techo de cristal no debería incluir únicamente la representación equitativa en los puestos de mayor responsabilidad dentro de las organizaciones, puesto que al ser un fenómeno multidimensional necesitamos atender a varias variables para demostrar su existencia, así como su evolución.

Por ello, proponemos cuantificar el techo de cristal a través de un indicador sintético multidimensional que recoja diferentes aspectos que se han detectado como relevantes en la revisión de la literatura. Según la definición de la OCDE, un indicador sintético es aquel que "mide conceptos multidimensionales que no pueden ser capturados por un indicador individual" (OECD, 2008) y establece una orientación sobre los pasos a seguir para su construcción.

Siguiendo el manual elaborado por la OCDE (OECD, 2008) y las recomendaciones de expertos en la construcción de indicadores sintéticos (Nardo et al., 2005; Hausmann et al., 2009), se deben seguir una serie de etapas relacionadas con diferentes decisiones metodológicas. En primer lugar, se establece un marco teórico para la incorporación de los ámbitos o dimensiones a incluir en el indicador sintético (incluido en el apartado 2.1). En segundo lugar, se seleccionan las variables dentro de cada dimensión y se preparan estadísticamente (imputación de datos perdidos, transformación en indicadores, análisis de correlación y multivariante, normalización para eliminar las diferencias en unidades de medida, etc.). En tercer lugar, se selecciona y diseña el procedimiento estadístico de asignación de las ponderaciones a cada indicador, para en un paso posterior, realizar la agregación y obtención del indicador sintético. Por último, se debe desarrollar y aplicar un proceso de validación, que incluya análisis de robustez y sensibilidad.

### 3.1. Selección de variables y bases de datos

Con respecto a la primera etapa en la elaboración del índice, el marco teórico desarrollado en el apartado 2.1. sienta las bases conceptuales para la inclusión de las dimensiones relevantes para la aproximación del techo de cristal, cuya selección final también está determinada por la disponibilidad de información estadística, detallada en el apartado de la descripción de bases de datos expuesta en la tabla 3.

Cabe destacar que, en todos los casos, se han seleccionado variables con periodicidad anual, fácilmente accesibles y de fuentes oficiales, lo que facilita la elaboración del índice y su continuidad en el tiempo.

**Tabla 3.**
**Relación de variables del IRTC**

| Dominio | Variable | Índices en los que aparece | Fuente |
|---|---|---|---|
| Educación | Educación superior | GDI, GGI, GEI, GII, GCI | MEFP |
| Mercado laboral | Empleo | GGI, WE3, GII, GCI | INE |
| | Actividad | GGI, WE3, GII, GCI | INE |
| Salarios | Mediana del salario | GDI, GEI, GCI | INE |
| | Salario de la alta ocupación | GEI, GCI | INE |
| Parcialidad | Parcialidad | GEI, GCI | INE |
| Poder económico | Puestos de dirección | GEM, GEI, SIGI, WE3, GCI | INE |
| Poder político | Parlamento | GEM, GGI, GEI, SIGI, WE3, GII, GCI | Instituto de las Mujeres |
| | Gobierno Autonómico | GEM, GEI, SIGI | Instituto de las Mujeres |

Tabla 3. cont.
**Relación de variables del IRTC**

| Dominio | Variable | Índices en los que aparece | Fuente |
|---|---|---|---|
| | Alcaldías | GEM, GEI, SIGI | Instituto de las Mujeres |
| | Concejalías | GEM, GGI, GEI, SIGI | Instituto de las Mujeres |
| Excedencias y prestaciones | Excedencia por cuidado de familiares | GEI | MTMSS |
| | Excedencia por cuidado de hijos | GEI | MTMSS |
| | Prestación por maternidad | GCI | INSS |
| Parcialidad cuidados | Parcialidad por cuidado de hijos | | INE |

**Notas:** MEFP = Ministerio de Educación y Formación Profesional, INE = Instituto Nacional de Estadística, MTMSS = Ministerio de Trabajo, Migraciones y Seguridad Social, INSS = Instituto Nacional de Seguridad Social
**Fuente:** Elaboración propia.

## 3.2. Transformación y normalización de indicadores

La normalización incluye todas las conversiones requeridas no sólo para homogeneizar las unidades de medida, sino también para asegurar que los valores de los indicadores individuales no se compensan entre ellos. En nuestra propuesta de IRTC se ha seguido la metodología empleada por el Instituto Europeo para la Igualdad de Género para la elaboración del GEI (EIGE, 2017) en el que, como se detalla a continuación, cada una de las variables consideradas se transforman en la denominada brecha de género.

Es importante señalar que nuestro índice mide la presencia de techo de cristal en sentido inverso, esto es, cuanto mayor (menor) es el valor del índice, menor (mayor) es la presencia de techo de cristal. En este sentido, la primera transformación realizada sobre aquellas variables con un efecto positivo sobre la presencia de techo de cristal, como la parcialidad, ha sido el cálculo de su valor complementario. Asimismo, y con el objetivo de comparar poblaciones de distinto tamaño y estructura, todas las variables, con la excepción de las salariales, están expresadas en términos relativos o como ratios respecto de su población de referencia. Para las variables dentro del dominio de poder político se ha empleado un promedio de 3 años, mientras que la población de referencia empleada es el promedio de 3 años de la población de 18 años y más. Una vez obtenidas las ratios, para cada variable se calcula la brecha (*B*) de género según la siguiente expresión:

$$B(X_{it}) = \begin{cases} \frac{X_{wit}}{X_{ait}} - 1 & si \ \frac{X_{wit}}{X_{ait}} \leq 1 \\ 0 & si \ \frac{X_{wit}}{X_{ait}} > 1 \end{cases} \qquad (1)$$

en donde $X_{it}$ representa el valor de cada una de las variables consideradas expresada en términos relativos para la comunidad autónoma *i* en el año *t*, mientras que $X_{wit}$ y $X_{ait}$ representan el valor de cada una de las variables para las mujeres y en promedio (mujeres y hombres) respectivamente, expresada en términos relativos para la comunidad autónoma *i* en el año *t*. Como puede apreciarse, y con el fin de evitar efectos compensatorios dentro de una misma comunidad autónoma entre distintas variables, el valor de la brecha de género queda censurado a cero en aquellas variables o dominios en los que las mujeres presentan una mejor situación que los hombres[15]. De esta forma, evitamos que se produzcan situaciones en donde, en

[15] Un procedimiento similar para evitar efectos compensatorios es utilizado en la elaboración del Gender Equity Index (Social Watch, 2012) y del Global Gender Gap Index (WEF, 2021).

una determinada región, la presencia de techo de cristal en una determinada variable o dominio quede enmascarada al compensarse por la mejor situación de las mujeres frente a los hombres en otras variables o dominios. La brecha de género toma valores en el intervalo [0,1], en donde cero implica ausencia de techo de cristal.

Con el fin de comparar las distintas variables y facilitar su agregación en un único indicador, se calcula una métrica de brecha de género (MB) (ver sección 2.2 de EIGE, 2017):

$$MB(X_{it}) = 1 + [\alpha(X_{it}) \cdot (1 - B(X_{it}))] \cdot 99 \tag{2}$$

en donde *(1-B($X_{it}$))* es el complementario de la brecha de género que toma valores en el intervalo [0,1], de manera que un valor mayor implica una menor presencia de brecha de género. Por su parte, $\alpha(X_{it})$ es un coeficiente corrector cuyo objetivo es comparar, para cada variable, los niveles alcanzados entre las diferentes comunidades autónomas, penalizando a aquellas comunidades que presentan una peor situación. Este coeficiente asegura que un resultado alto en la métrica de brecha de género en una comunidad será indicativo tanto de una baja presencia de techo de cristal en la misma, como de una buena posición de la variable para el conjunto de la población con relación al resto de comunidades autónomas. Para que los valores de la métrica estén entre 1 y 100 se multiplica el complementario corregido de la brecha de género por 99 y se suma 1 al resultado. El coeficiente corrector se calcula según la siguiente expresión (ver sección 2.2.2 de EIGE, 2017),

$$\alpha(X_{it}) = \left(\frac{X_{Tit}}{\max(X_{Ti2008}, X_{Ti2009}, \ldots, X_{Ti2018})}\right)^{1/2} \tag{3}$$

en donde $X_{Tit}$ es el valor de cada una de las variables para el total de la población (hombres y mujeres). De este modo, para cada variable, comunidad autónoma y año, se compara el valor de dicha variable para el conjunto de la población con el de aquella comunidad autónoma que presenta una mejor situación.

### 3.3. Pesos de los indicadores

En la asignación de ponderaciones, la literatura ofrece diferentes opciones metodológicas y no existe consenso sobre la idoneidad de un proceso específico (OECD, 2008), siendo necesario analizar cada caso en concreto. Una parte importante de los trabajos en los que se construyen indicadores sintéticos utilizan proyecciones lineales unidimensionales que generan medias ponderadas de indicadores simples, siendo la metodología más extendida aquella cuya ponderación es idéntica para cada variable o indicador simple (Arranz et al., 2018). Este procedimiento tiene limitaciones. En primer lugar, es necesario que las variables originales que van a formar parte del indicador sintético tengan las mismas unidades de medida y, en segundo lugar, ignora las relaciones causales existentes entre las variables originales que van a formar parte del indicador sintético. Según Nardo et al. (2005) el aplicar pesos iguales a las variables desequilibra las dimensiones con diferente número de variables y puede resultar en un indicador descompensado. “Promediar las diferentes variables daría implícitamente más peso a la medida que presenta la mayor variabilidad o desviación estándar” (Hausmann et al., 2009). Por lo tanto, al menos debe tenerse en cuenta este aspecto y permitir que las variables sean ponderadas teniendo en cuenta sus desviaciones estándar.

Para evitar los problemas anteriores aparecen diferentes técnicas de análisis multivariante. Se podrían utilizar modelos estadísticos como el Análisis de Componentes Principales (ACP) o el análisis factorial para agrupar indicadores individuales (Nicoletti et al., 2003). Estos métodos dan cuenta de la mayor variación en el conjunto de datos, utilizando el menor número posible de factores que reflejan la dimensión "estadística" subyacente del conjunto total. La ponderación (peso) solo interviene para corregir la información superpuesta de dos o más indicadores correlacionados, y no es una medida de la importancia teórica de los indicadores. Estas ponderaciones solo se pueden estimar si existe correlación entre las variables.

Para la construcción de nuestro indicador hemos elegido esta técnica estadística, que está especialmente indicada cuando no existe un consenso sobre la importancia relativa de las variables originales dentro del indicador sintético. En nuestro caso, este método no se utiliza para reducir la dimensión de la información, puesto que se quiere utilizar la información completa, sino para calcular el peso que cada variable original tendría en el IRTC.

## 3.4. Agregación de indicadores

En la agregación de indicadores se parte del cálculo de los componentes principales, sus autovalores y la varianza explicada por cada componente. El IRTC para cada comunidad autónoma i y año se construiría a partir de la suma ponderada de los valores de los "p" componentes, donde la ponderación ($w_j$) sería el porcentaje de varianza explicada por cada componente principal ($CP_{jt}$):

$$IRTC_{it} = \sum_{j=1}^{p} w_j CP_{jt} \qquad (4)$$

Sin embargo, resulta más útil obtener el valor del indicador directamente a partir de las variables originales transformadas de la siguiente forma:

$$IRTC_{it} = \frac{1}{\sqrt{\sum_{l=1}^{k} \lambda_l^2}} \sum_{l=1}^{k} \sum_{j=1}^{k} \rho_{jl} MB(X_{it}) \qquad (5)$$

donde $MB(Xi_t)$ es la métrica de brecha de género y $\rho_{jl}$ es la carga factorial del componente l en la variable j y $\lambda_j$, el autovalor asociado al componente l.

El indicador construido según la ecuación [5] es el resultado de una agregación lineal de las variables. El tipo de agregación es otra de las decisiones relevantes a la hora de construir un indicador sintético. El método de agregación lineal es útil cuando todos los indicadores individuales tienen la misma unidad de medida (OECD, 2008), mientras que las agregaciones geométricas (en las que los indicadores se multiplican y las ponderaciones aparecen como exponentes) son apropiados cuando los indicadores individuales no son comparables y se expresan en diferentes escalas de razón.

## 3.5. Análisis de robustez

Con fines comparativos, y como análisis de robustez del índice obtenido mediante ACP, se han empleado otros tres métodos para asignar ponderaciones, siendo en todos los casos agregados linealmente.

El primero es el que hemos llamado TE por tener ponderaciones similares a las utilizadas por The Economist en la elaboración de su Glass Ceiling Index. De forma que se ha ponderado cada dominio de forma equivalente a las ponderaciones que dichos expertos habían considerado, dando el mismo peso dentro del dominio.

El llamado HS hace referencia a las ponderaciones resultantes de aplicar el método de Hausmann (Hausmann et al., 2009), que consiste en calcular el peso de cada variable considerando su variabilidad dentro del dominio, y considerando para cada dominio un peso igual en proporción al número total de dominios en el índice.

Y, por último, hemos considerado unas ponderaciones equitativas para el denominado EQ. Dado que tenemos 8 dominios, cada uno tiene un peso de 1/8 sobre el total. Y, de la misma forma, a las variables se las ha dado un mismo peso sobre su dominio, con lo que si, como es el caso del dominio “Mercado laboral”, hay dos variables, cada una tiene un peso de 1/2.

**Tabla 4.**
**Ponderaciones de variables y dominios del índice**

| | | Índice ACP | | Índice TE | | Índice HS | | Índice EQ | |
|---|---|---|---|---|---|---|---|---|---|
| **Dominio** | **Variable** | Peso Dominio | Peso Variable | Peso Dominio | Peso Variable | Peso Dominio | Peso Variable | Peso Dominio | Peso Variable |
| Educación | Educación superior | 0,042 | 0,042 | 0,15 | 1 | 0,125 | 1 | 0,125 | 1 |
| Mercado laboral | Empleo | 0,142 | 0,083 | 0,15 | 0,5 | 0,125 | 0,49 | 0,125 | 0,5 |
| | Actividad | | 0,059 | | 0,5 | | 0,51 | | 0,5 |
| Salarios | Mediana del salario | 0,22 | 0,12 | 0,15 | 0,5 | 0,125 | 0,47 | 0,125 | 0,5 |
| | Salario de la alta ocupación | | 0,1 | | 0,5 | | 0,53 | | 0,5 |
| Parcialidad | Parcialidad | 0,046 | 0,046 | 0,1 | 1 | 0,125 | 1 | 0,125 | 1 |
| Poder económico | Puestos de dirección | 0,023 | 0,023 | 0,15 | 1 | 0,125 | 1 | 0,125 | 1 |
| Poder político | Parlamento | 0,252 | 0,061 | 0,1 | 0,25 | 0,125 | 0,29 | 0,125 | 0,25 |
| | Gobierno Autonómico | | 0,048 | | 0,25 | | 0,14 | | 0,25 |
| | Alcaldías | | 0,077 | | 0,25 | | 0,31 | | 0,25 |
| | Concejalías | | 0,066 | | 0,25 | | 0,26 | | 0,25 |
| Excedencias y prestaciones | Excedencia por cuidado de familiares | 0,227 | 0,094 | 0,1 | 0,33 | 0,125 | 0,14 | 0,125 | 0,33 |
| | Excedencia por cuidado de hijos | | 0,076 | | 0,33 | | 0,4 | | 0,33 |
| | Prestación por maternidad | | 0,057 | | 0,33 | | 0,46 | | 0,33 |
| Parcialidad cuidados | Parcialidad por cuidado de hijos | 0,047 | 0,047 | 0,1 | 1 | 0,125 | 1 | 0,125 | 1 |

**Fuente:** Elaboración propia.

# 4. Resultados

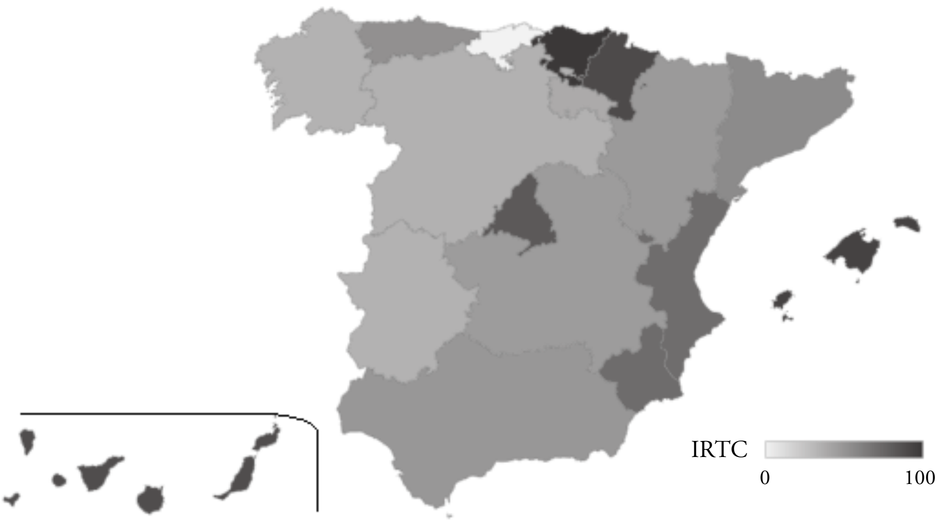
## 4.1. Resultados del Índice Regional de Techo de Cristal

Siguiendo la metodología expuesta en el apartado previo, hemos procedido a calcular el IRTC para el periodo 2008-2018. Los resultados del IRTC, calculando los pesos por ACP que es nuestra propuesta de indicador, se presentan en la Tabla 5, incluyendo el valor del índice y la posición de la comunidad autónoma siguiendo un ranking de mayor a menor valor del IRTC (esto es, de menor a mayor techo de cristal). Atendiendo a los resultados para el año 2018, se observa que las regiones con una menor presencia de techo de cristal son País Vasco, Baleares, Navarra y Canarias. Por su parte, Cantabria aparece como la región con mayor techo de cristal, seguida de Galicia, Extremadura y Castilla y León. Si atendemos al coeficiente de correlación entre los valores promediados a lo largo del tiempo para cada comunidad del IRTC y la métrica de brecha de género de las distintas variables que componen el índice, las mayores correlaciones las encontramos entre las variables del dominio de salarios (mediana del salario 0,75; salario de la alta ocupación 0,72), algunas variables del dominio poder político (alcaldías 0,63; concejalías 0,59), la tasa de actividad (0,58) y excedencias por cuidado de familiares (0,57). En términos generales, estas variables son las que estarían explicando en mayor medida las diferencias observadas entre las distintas comunidades autónomas.

Los resultados que se obtienen al aplicar distintas ponderaciones para los coeficientes de las dimensiones, tal y como se explica en el apartado de metodología (indicadores TE, HS, EQ) para el análisis de robustez, muestran resultados similares. En la Tabla 5 se presentan los coeficientes de correlación entre el IRTC-ACP y el resto. Salvo en el periodo 2008-2011 y en el año 2016, el coeficiente de correlación se encuentra por encima de 0,6, observándose en el último año (2018) una alta correlación próxima a 0,9.

Con el fin de estudiar la posible presencia de algún tipo de relación espacial, el mapa del gráfico 2 se ha elaborado empleando los datos del IRTC (calculado con ACP, a partir de ahora) para el año 2018. El gráfico no muestra ningún tipo de patrón espacial. Este resultado se confirma al calcular el estadístico I de Moran para el análisis de autocorrelación espacial, que toma un valor muy cercano a cero (-0,069), sugiriendo la presencia de un patrón espacial aleatorio.

**GRÁFICO 2.**
**Índice Regional de Techo de Cristal para España, 2018**




**Notas:** valores tipificados según normalización min-max entre 0 y 100.
**Fuente:** Elaboración propia.

Los resultados comparativos de la Tabla 5 para el periodo analizado (2008-2018) muestran que la situación ha mejorado de forma generalizada para todas las comunidades autónomas. En particular, las regiones que han experimentado un mayor incremento en el valor del índice son Murcia (incremento de 7,6 puntos), Navarra (incremento de 6,2 puntos), Comunidad Valenciana (incremento de 6,1 puntos) y País Vasco (incremento de 5,2 puntos). En el lado opuesto se sitúan Cantabria y Castilla-La Mancha, en donde el incremento registrado fue tan solo de 0,1 y 0,9 puntos respectivamente. Si bien es cierto que existe cierta heterogeneidad entre regiones, el progreso general observado en el índice se debe principalmente a la buena evolución del dominio de poder político, el dominio de salarios y el dominio de excedencias, aunque este último todavía presenta valores muy bajos. En el conjunto de España la presencia de mujeres en los parlamentos autonómicos aumentó en el periodo considerado en casi 4 puntos porcentuales (desde un 41,7% hasta el 45,4%), siendo dicho incremento de poco más de 3 puntos porcentuales en los gobiernos autonómicos (desde el 40,1% hasta el 43,3%) y de aproximadamente 5 puntos en alcaldías (desde un 14,6% hasta el 19,1%) y concejalías (desde un 30,5% hasta el 35,6%). Atendiendo al dominio de salarios, si bien es cierto que la brecha salarial se ha incrementado levemente en el conjunto de España (desde un 20,8% hasta el 21,4%), en algunas regiones el descenso ha sido notable. Ejemplo de ello es Navarra, en donde la brecha salarial se ha reducido en más de 8 puntos porcentuales, y

Baleares y Madrid, con caídas de 3 puntos porcentuales. Dentro del dominio de excedencias, el número de excedencias por cuidado de descendientes solicitados por hombres se ha incrementado de forma muy significativa en el conjunto de España pasando a representar el 8,7% del total de excedencias desde un 3,9%. De forma similar, el número de excedencias para el cuidado de familiares solicitadas por hombres se incrementó desde un 15,5% en 2008 hasta el 17,6% del total de excedencias en 2018.

**Tabla 5.**
**Valores y ranking del Índice Regional de Techo de Cristal, 2008-2018**

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Andalucía | 54,5 (6) | 55,9 (7) | 55,3 (6) | 55,3 (5) | 54,4 (5) | 55,2 (5) | 54,6 (5) | 55,8 (8) | 55,8 (9) | 56,3 (9) | 56,4 (10) |
| Aragón | 51,7 (14) | 52,4 (16) | 51,7 (16) | 50,5 (17) | 48,9 (17) | 50,2 (17) | 49,8 (17) | 51,9 (16) | 54,0 (15) | 55,2 (13) | 56,2 (11) |
| Asturias | 53,7 (8) | 54,3 (9) | 52,2 (15) | 52,4 (13) | 51,2 (13) | 53,7 (9) | 53,9 (7) | 56,4 (7) | 56,4 (8) | 57,2 (8) | 56,7 (9) |
| Baleares | 56,6 (2) | 57,2 (2) | 57,5 (1) | 56,7 (3) | 55,1 (4) | 55,6 (4) | 55,6 (3) | 57,9 (3) | 59,7 (2) | 59,9 (3) | 61,1 (2) |
| Canarias | 59,1 (1) | 55,9 (6) | 55,1 (7) | 54,9 (6) | 54,2 (6) | 55,8 (3) | 55,0 (4) | 57,2 (4) | 59,1 (3) | 60,0 (2) | 60,5 (4) |
| Cantabria | 51,1 (17) | 51,6 (17) | 51,1 (17) | 51,8 (14) | 50,9 (14) | 51,6 (15) | 51,1 (15) | 51,6 (17) | 52,5 (17) | 52,5 (17) | 51,3 (17) |
| Castilla y León | 51,8 (13) | 53,0 (14) | 52,5 (12) | 53,3 (11) | 51,9 (11) | 52,8 (11) | 53,2 (11) | 54,7 (13) | 55,0 (14) | 54,1 (16) | 54,9 (14) |
| Castilla La Mancha | 55,2 (5) | 56,1 (4) | 55,3 (5) | 54,4 (7) | 52,8 (10) | 53,7 (10) | 54,1 (6) | 55,3 (10) | 55,1 (11) | 55,4 (11) | 56,1 (12) |
| Cataluña | 53,3 (9) | 53,7 (12) | 53,6 (10) | 53,5 (9) | 53,4 (9) | 54,1 (7) | 53,6 (10) | 54,8 (12) | 55,5 (10) | 56,2 (10) | 57,1 (8) |
| Comunidad Valenciana | 52,6 (10) | 53,7 (11) | 53,9 (9) | 54,2 (8) | 53,5 (8) | 54,5 (6) | 53,7 (9) | 55,4 (9) | 56,9 (7) | 57,4 (7) | 58,7 (7) |
| Extremadura | 52,6 (11) | 54,3 (8) | 53,2 (11) | 52,6 (12) | 50,5 (15) | 51,9 (12) | 50,5 (16) | 56,7 (5) | 55,1 (12) | 54,5 (14) | 54,8 (16) |
| Galicia | 51,6 (15) | 53,2 (13) | 52,3 (13) | 51,2 (16) | 50,1 (16) | 51,8 (13) | 51,7 (14) | 53,2 (15) | 53,3 (16) | 54,4 (15) | 54,8 (15) |
| Madrid | 55,5 (4) | 56,1 (5) | 56,8 (3) | 57,6 (1) | 57,9 (1) | 58,5 (2) | 58,3 (2) | 58,9 (2) | 58,6 (4) | 59,0 (5) | 59,8 (5) |
| Murcia | 51,2 (16) | 54,3 (10) | 54,2 (8) | 53,4 (10) | 51,7 (12) | 51,5 (16) | 52,1 (13) | 55,0 (11) | 58,5 (5) | 59,6 (4) | 58,8 (6) |
| Navarra | 54,5 (7) | 56,6 (3) | 56,1 (4) | 55,9 (4) | 54,1 (7) | 53,9 (8) | 53,9 (8) | 56,6 (6) | 57,6 (6) | 58,7 (6) | 60,7 (3) |
| País Vasco | 56,5 (3) | 57,4 (1) | 57,3 (2) | 57,4 (2) | 56,8 (2) | 58,8 (1) | 58,4 (1) | 59,7 (1) | 60,5 (1) | 61,4 (1) | 61,7 (1) |
| La Rioja | 51,9 (12) | 52,4 (15) | 52,2 (14) | 51,3 (15) | 55,3 (3) | 51,7 (14) | 52,8 (12) | 53,5 (14) | 55,1 (13) | 55,4 (12) | 55,3 (13) |
| Correlación con: | | | | | | | | | | | |
| TE | 0,56 | 0,49 | 0,45 | 0,79 | 0,80 | 0,80 | 0,76 | 0,63 | 0,44 | 0,75 | 0,87 |
| HS | 0,64 | 0,62 | 0,56 | 0,82 | 0,75 | 0,83 | 0,80 | 0,60 | 0,52 | 0,82 | 0,90 |
| EQ | 0,65 | 0,69 | 0,61 | 0,83 | 0,77 | 0,85 | 0,81 | 0,61 | 0,56 | 0,85 | 0,91 |

**Notas:** el valor entre paréntesis indica el puesto ocupado en cada año.
**Fuente:** elaboración propia.

La evolución positiva del dominio de poder político puede explicarse por la aprobación de la Ley Orgánica 3/2007 para la igualdad efectiva entre hombres y mujeres, que modificó la Ley Orgánica 5/1985 del Régimen Electoral General con el objetivo de asegurar una representación suficientemente significativa de ambos sexos en órganos y cargos de representación política. De forma que en los sucesivos años el poder político ha ido avanzando hacia la paridad al tiempo que el aumento de la conciencia de los partidos políticos gracias a esta norma ha contribuido a reforzar el propio objetivo (Espí-Hernández, 2017). Un análisis por Comunidades Autónomas (Uribe Otalora, 2013) muestra que diez de ellas mejoran porcentualmente la presencia de senadoras electas a raíz de la Ley de Igualdad durante el período 2008-2011, siete repiten resultados y sólo Andalucía y La Rioja retroceden respecto a 2004 (Andalucía pasa de un 37,5% a un 25% y La Rioja de un 50% a un 25%). En cuanto al porcentaje de diputadas, también de forma generalizada se han mejorado las cifras de 2008 en Aragón, Asturias, Baleares, Canarias, Cantabria, Galicia, Madrid, La Rioja y la Comunidad Valenciana, situándose prácticamente todas ellas por encima del 40%.

Del mismo modo, y como posible causa de la evolución positiva del dominio de salarios, esta Ley Orgánica 3/2007 también se erige en el ámbito de las relaciones laborales, abordando expresamente que la igualdad de trato y oportunidades entre mujeres y hombres incluye las condiciones laborales relativas a las retribuciones. Además, se establece la obligación, para empresas con más de 250 trabajadores o si lo requiere el convenio colectivo, de elaborar y aplicar un Plan de Igualdad con medidas para eliminar las discriminaciones por razón de sexo, haciendo referencia expresa a las retribuciones (Vela Díaz, 2019).

A su vez, algunas comunidades que contaban con leyes autonómicas de igualdad de género con anterioridad a la norma estatal ocupan puestos relativamente altos en el indicador de techo de cristal. Ejemplo de ello es Navarra, Comunidad Valenciana y el País Vasco, cuyas leyes autonómicas de igualdad datan de 2002, 2003 y 2005 respectivamente.

Los dominios que han tenido una aportación negativa son el dominio de poder económico, que ha experimentado una importante caída como consecuencia de la mala evolución de la variable de puestos de dirección y, en menor medida, el dominio de parcialidad.

En relación con los cambios que se han producido en el ranking del índice entre las distintas comunidades entre 2008 y 2018, se puede apreciar que Murcia es con diferencia la comunidad que ha escalado más puestos en el ranking, consecuencia principalmente de la importante mejora en los dominios de educación y de poder político. Las otras regiones que han adelantado puestos son Navarra, Aragón, País Vasco, Comunidad Valenciana y Cataluña. En contraposición, Castilla-La Mancha ha perdido un total de 7 puestos en el ranking, debido a la reducida mejora experimentada en los distintos dominios en comparación con el resto de comunidades autónomas.

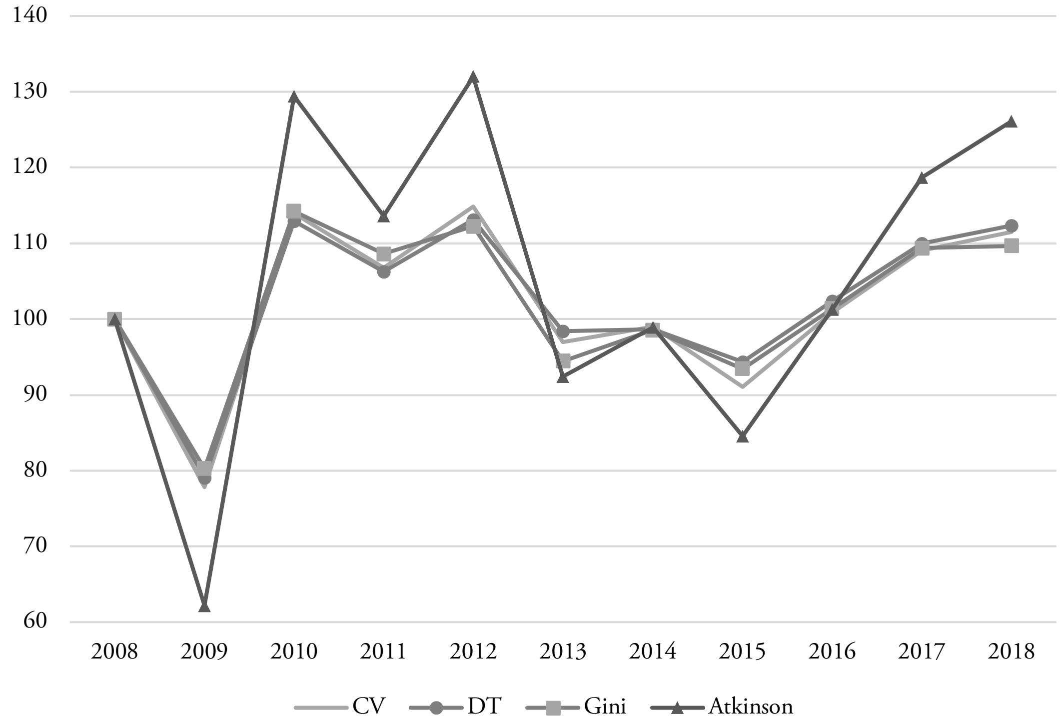
### 4.2. Análisis de convergencia

En este apartado se analiza más a fondo la evolución del IRTC aplicando los conceptos clásicos de convergencia aplicados en economía en temas de crecimiento económico. De forma específica se estudian los dos principales conceptos de convergencia generalmente aceptados: convergencia-$\sigma$ y convergencia-$\beta$ (Barro et al., 1991; Barro y Sala-i-Martin, 1992).

La presencia de convergencia-$\sigma$ implicaría una disminución en la dispersión del índice entre comunidades a lo largo del tiempo. El gráfico 3 muestra la evolución de cuatro indicadores de dispersión calculados para el periodo 2008-2018: el coeficiente de variación (CV), la desviación típica (DT), el índice de Gini y el índice de Atkinson. Estos indicadores presentan una evolución muy similar, con un incremento de la dispersión a lo largo del periodo considerado, a pesar de las importantes fluctuaciones observadas durante los primeros años de la muestra (2009-2013). Este incremento de la dispersión implica ausencia de convergencia-$\sigma$, lo que sugiere que, a pesar de la mejora generalizada experimentada con relación a la presencia del techo de cristal, las diferencias entre regiones se han acentuado en el tiempo.

**Gráfico 3.**
**Indicadores de dispersión para el análisis de convergencia-σ**

(valores normalizados 2008 = 100)




**Fuente:** Elaboración propia.

Por su parte, el concepto de convergencia-β[16] implicaría que aquellas regiones que presentan menores valores en el IRTC al principio del periodo son las que han experimentado una mayor mejora. De esta forma el índice tendería a tomar valores similares entre comunidades autónomas en el tiempo.

Para analizar la convergencia-β se estima la siguiente ecuación,

$$Ln\left(\frac{IRTC_{i,t}}{IRTC_{i,t-n}}\right) = \propto + \beta LnIRTC_{i,t-n} + \varepsilon_{it} \tag{6}$$

en donde en el lado izquierdo tenemos el logaritmo (*Ln*) del cociente entre el valor del índice en un momento final t y su valor en un momento inicial t-n (es decir, la tasa de crecimiento del IRTC entre t-n y t), mientras que en el lado derecho tenemos el logaritmo del índice en el valor inicial t-n. Para que exista convergencia beta, el parámetro estimado β tendría que ser negativo y estadísticamente significativo.

La ecuación planteada ha sido estimada de diferentes formas. En primer lugar, se ha realizado una estimación de sección cruzada por Mínimos Cuadrados Ordinarios (MCO) utilizando tan solo los datos del índice correspondientes a 2008 y 2018. En segundo lugar, se ha estimado la ecuación utilizando la información disponible para diferentes años en un panel de datos, mediante efectos fijos. En particular, la estimación se ha realizado de forma anual y utilizando intervalos o periodos de 2 a 5 años. Los resultados se muestran en la Tabla 6. En cada caso se muestra el valor estimado de los coeficientes y su correspondiente

[16] Los dos conceptos de convergencia analizados están estrechamente relacionados entre sí. Pues en efecto, la convergencia-β es condición necesaria (aunque no suficiente) para que exista convergencia-σ.

desviación típica, así como el R cuadrado y el valor del estadístico F para el contraste de la hipótesis nula de no significatividad conjunta de los parámetros estimados.

Los resultados de las estimaciones no muestran evidencia a favor de la presencia de convergencia beta. En el caso de la estimación por MCO de sección cruzada, el parámetro β es negativo, pero no es estadísticamente significativo. En el caso de la estimación mediante efectos fijos, el parámetro β es siempre positivo para los distintos intervalos de tiempo y estadísticamente significativo al 1%. Este resultado sugiere que aquellas regiones que presentan inicialmente mayores valores en el IRTC (menor presencia de techo de cristal) son las que han experimentado un incremento mayor en el IRCT.

**Tabla 6.**
**Resultados de las estimaciones para la convergencia-β**

| | **MCO Sección cruzada** | **Efectos fijos Datos de panel** | | | | |
|---|---|---|---|---|---|---|
| | | **anual** | **2 años** | **3 años** | **4 años** | **5 años** |
| LnIRTCi,t-n | -0,1517 (0,2282) | 0.5530*** (0.1323) | 0,8635*** (0,0739) | 1,2673*** (0,1018) | 1,6849*** (0,2993) | 1.3098*** |
| Constante | 0,6689 (0,9120) | -2.1953*** (0.5300) | -3,4385*** (0,2955) | -5,0488*** (0,4074) | -6,7028*** (1,1901) | -5.2178*** (0.6027) |
| Nº observaciones | 17 | 170 | 85 | 51 | 34 | 34 |
| $R^2$ | 0,03 | 0.25 | 0,33 | 0,31 | 0,32 | 0.37 |
| Estadístico F (p-valor) | 0,44 (0,52) | 40.56 (0.00) | 82,79 (0,00) | 156,36 (0,00) | 50,95 (0,00) | 82.41 (0.00) |
| Efectos fijos de tiempo | NO | SI | SI | SI | SI | SI |

**Notas:** significatividad estadística (***) 1%, (**) 5%, (*) 10%. Para el panel de 2 años se consideran 6 subperiodos: 2008-2010, 2010-2012, 2012-2014, 2014-2016, 2016-2018. Para el panel de 3 años se consideran 3 subperiodos: 2008-2011, 2011-2014, 2014-2017. Para el panel de 4 años se consideran 2 subperiodos: 2008-2012, 2012-2017. Para el periodo de 5 años se consideran 2 subperiodos: 2008-2013, 2013-2018.
**Fuente:** Elaboración propia.

## 5. Conclusiones

Esta es una era progresiva en la que las mujeres están empoderadas y trabajan de manera sistemática y beligerante para asegurarse de que luchan contra las inequidades y desigualdades de género que resultan en el techo de cristal. La necesidad de tener una medida única que incorpore diferentes aspectos relativos al fenómeno analizado nos ha impulsado a proponer la elaboración de un indicador sintético de techo de cristal para las diferentes regiones españolas.

Los resultados del IRTC, calculado para las distintas comunidades autónomas a lo largo del periodo 2008-2018, permiten obtener algunas conclusiones de interés. En primer lugar, y atendiendo a los datos más actuales, se observa que las regiones más favorables para la presencia femenina en puestos de poder y con una menor presencia de techo de cristal son País Vasco, Baleares, Navarra y Canarias. Mientras que Cantabria aparece como la región con mayores barreras, seguida de Galicia, Extremadura y Castilla y León.

En segundo lugar, los resultados del indicador propuesto muestran que la situación ha mejorado de forma generalizada para todas las comunidades autónomas durante el periodo analizado (2008-2018), siendo Murcia, Navarra, Comunidad Valenciana y País Vasco las regiones que han experimentado una mejor evolución. Dicho progreso se debe principalmente a la mejor posición del dominio de poder político, de salarios y de excedencias, si bien en este último los valores siguen siendo muy bajos.

En tercer lugar, el análisis de convergencia realizado no muestra evidencia ni a favor de la presencia de convergencia-σ ni a favor de convergencia-β. En este sentido se concluye que, a pesar de la mejora generalizada observada, se ha producido un incremento en las diferencias observadas en la presencia de techo de cristal en la última década.

Consideramos que estos resultados son muy relevantes en cuanto a la necesidad de conocer y analizar de forma específica qué ocurre en cada comunidad autónoma. Desde el punto de vista del diseño de políticas públicas dirigidas a reducir el techo de cristal, sería fundamental hacer un seguimiento de las diferentes dimensiones que se incluyen en el indicador, para determinar cómo pueden influir las políticas nacionales y las regionales en su evolución. Así mismo, la identificación de regiones donde las barreras a las mujeres son más fuertes deberían ser un objetivo prioritario.

La concienciación del problema y las medidas políticas están haciendo que las mujeres cada vez estén más representadas en las jerarquías de poder, pero el techo de cristal sigue siendo un problema, poniendo de manifiesto que la igualdad de género es una meta por la que seguir luchando. Por ello, las organizaciones e instituciones deben ser conscientes de que romper con el techo de cristal es complejo para las mujeres, y deben actuar de forma activa para ayudar en este objetivo a través de políticas de flexibilización horaria, medidas de conciliación, procesos ciegos en los ascensos, o formación en liderazgo, entre otras.

Este artículo se ha focalizado en el diseño del indicador sintético del techo de cristal para el cálculo a nivel regional. En relación con las líneas de trabajo que se abren a partir de este indicador pasa por varios análisis. En primer lugar, la utilización de diferentes opciones metodológicas, tanto en la inclusión de las variables, como en su agregación, de forma que se pueda hacer un análisis de sensibilidad y robustez más amplio. En segundo lugar, tiene interés en sí mismo llevar a cabo un análisis exhaustivo de las diferencias regionales por dimensiones y variables, que permita justificar las principales causas del techo de cristal. Además, se pretenden estudiar posibles relaciones causales entre diferentes variables socioeconómicas de las regiones y el indicador de techo de cristal, pudiendo utilizar metodologías de datos de panel para las regiones y los diferentes periodos.

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## Anexos

**Tabla A1.**
**Estadísticos descriptivos de las variables del IRTC (mujeres)**

| Dominio | Variable | Media | Desviación típica | Desviación típica (between) | Desviación típica (within) | Mínimo | Máximo |
|---|---|---|---|---|---|---|---|
| Educación | Educación superior (% pob.) | 35,2 | 6,9 | 6.2 | 3.3 | 23,0 | 51,3 |
| Mercado laboral | Empleo (tasa %) | 41,7 | 5,0 | 4.9 | 1.6 | 30,0 | 52,6 |
| | Actividad (tasa %) | 52,1 | 3,9 | 3.9 | 1.2 | 42,5 | 61,4 |
| Salarios | Mediana del salario (€) | 16.284 | 1.676 | 1.616 | 579 | 13.626 | 21.359 |
| | Salario de la alta ocupación (€) | 27.841 | 2.123 | 1.847 | 1.131 | 23.851 | 34.306 |
| Parcialidad | Parcialidad (tasa %) | 24,4 | 3,4 | 3.1 | 1.7 | 17,3 | 32,1 |
| Poder económico | Puestos de dirección (% ocu.) | 3,7 | 1,7 | 0.5 | 1.6 | 1,3 | 8,6 |
| Poder político | Parlamento (% pob.) | 4,2 | 2,4 | 2.4 | 0.5 | 1,5 | 11,4 |
| | Gobierno Autonómico (% pob.) | 0,5 | 0,5 | 0.3 | 0.3 | 0,0 | 2,3 |
| | Alcaldías (% pob.) | 9,7 | 9,3 | 9.4 | 1.5 | 1,0 | 34,8 |
| | Concejalías (% pob.) | 146 | 110 | 94.7 | 59.6 | 13 | 680 |
| Excedencias y prestaciones | Exc. cuidado familiares (% ocu.) | 0,8 | 0,6 | 0.5 | 0.3 | 0,1 | 3,4 |
| | Exc. cuidado de hijos (% ocu.) | 5,5 | 8,6 | 5.7 | 6.6 | 0,5 | 67,7 |
| | Prestación maternidad (% ocu.) | 34,6 | 5,9 | 4.5 | 3.9 | 21,0 | 51,2 |
| Parcialidad cuidados | Parc. Cuidado de hijos (% tasa) | 5,5 | 1,5 | 1.3 | 0.8 | 1,9 | 9,8 |

**Notas:** todas las variables se refieren a la población de mujeres. La variable de educación y las variables de poder político están expresadas como número de mujeres sobre la población de mujeres mayor de 18 años. La variable de puestos de dirección y las variables de excedencias y prestaciones están expresadas sobre el número de mujeres ocupadas.
**Fuente:** elaboración propia.

TABLA A2.
**Media de las variables del IRTC (mujeres)**

| Variable | Andalucía | Aragón | Asturias | Balears, Illes | Canarias | Cantabria | Castilla - La Mancha | Castilla y León |
|---|---|---|---|---|---|---|---|---|
| Educación superior (% pob.) | 28,8 | 36,7 | 38,3 | 28,7 | 28,5 | 38,7 | 28,0 | 37,2 |
| Empleo (tasa %) | 34,8 | 43,7 | 38,3 | 49,2 | 39,9 | 42,1 | 36,5 | 39,0 |
| Actividad (tasa %) | 50,7 | 52,4 | 46,4 | 59,3 | 55,4 | 49,7 | 50,0 | 47,9 |
| Mediana del salario (€) | 15.303 | 16.326 | 15.729 | 17.154 | 15.230 | 15.117 | 15.386 | 15.551 |
| Salario de la alta ocupación: (€) | 26.607 | 27.470 | 28.531 | 27.840 | 28.056 | 26.494 | 26759 | 26719 |
| Parcialidad (tasa %) | 27,2 | 25,2 | 21,9 | 20,1 | 21,2 | 21,7 | 24,7 | 25,7 |
| Puestos de dirección (% ocu.) | 3,6 | 3,8 | 4,5 | 4,5 | 3,6 | 3,9 | 2,8 | 3,4 |
| Parlamento (% pob.) | 1,5 | 4,7 | 3,9 | 6,1 | 3,0 | 6,3 | 2,4 | 4,0 |
| Gobierno Autonómico (% pob.) | 0,1 | 0,4 | 0,6 | 0,6 | 0,4 | 0,8 | 0,3 | 0,3 |
| Alcaldías (% pob.) | 4,5 | 21,3 | 3,2 | 2,1 | 1,7 | 4,1 | 21,5 | 31,8 |
| Concejalías (% pob.) | 104,7 | 189,0 | 73,4 | 78,0 | 62,6 | 124,5 | 246,1 | 281,7 |
| Exc. cuidado familiares (% ocu.) | 0,5 | 1,0 | 0,4 | 0,5 | 0,2 | 0,6 | 0,8 | 0,7 |
| Exc. cuidado de hijos (% ocu.) | 2,9 | 4,9 | 1,8 | 3,7 | 1,4 | 2,5 | 6,3 | 4,4 |
| Prestación maternidad (% ocu.) | 43,6 | 33,9 | 26,2 | 32,3 | 29,0 | 32,3 | 35,9 | 30,2 |
| Parc. Cuidado de hijos (% tasa) | 4,8 | 6,9 | 5,0 | 4,7 | 2,7 | 4,9 | 5,9 | 5,5 |

**Notas:** todas las variables se refieren a la población de mujeres. La variable de educación y las variables de poder político están expresadas como número de mujeres sobre la población de mujeres mayor de 18 años. La variable de puestos de dirección y las variables de excedencias y prestaciones están expresadas sobre el número de mujeres ocupadas.
**Fuente:** elaboración propia.

TABLA A2. CONT.
**Media de las variables del IRTC (mujeres)**

| Variable | Cataluña | Comunidad Valenciana | Extremadura | Galicia | La Rioja | Comunidad de Madrid | Murcia | Navarra | País Vasco |
|---|---|---|---|---|---|---|---|---|---|
| Educación superior (% pob.) | 37,3 | 32,7 | 27,4 | 35,4 | 38.2 | 44,9 | 28,3 | 43,6 | 46,5 |
| Empleo (tasa %) | 47,2 | 40,9 | 32,4 | 40,3 | 44.3 | 49,5 | 40,1 | 46,5 | 44,8 |
| Actividad (tasa %) | 56,9 | 52,8 | 46,5 | 48,7 | 53.0 | 58,8 | 52,5 | 53,9 | 51,5 |
| Mediana del salario (€) | 18.094 | 15.432 | 14.742 | 15.104 | 15.919 | 18.665 | 14.524 | 18.461 | 20.097 |
| Salario de la alta ocupación: (€) | 29.276 | 26.469 | 26.364 | 26.239 | 26.984 | 32.138 | 27.341 | 27.698 | 32.317 |
| Parcialidad (tasa %) | 21,9 | 28,1 | 27,7 | 21,2 | 27.0 | 19,6 | 24,9 | 28,5 | 27,8 |
| Puestos de dirección (% ocu.) | 4,2 | 3,7 | 3,5 | 3,9 | 3.6 | 4,4 | 2,9 | 3,5 | 3,2 |
| Parlamento (% pob.) | 1,7 | 2,1 | 6,1 | 2,5 | 10.4 | 2,0 | 3,0 | 7,6 | 3,9 |
| Gobierno Autonómico (% pob.) | 0,1 | 0,2 | 0,4 | 0,3 | 1.3 | 0,1 | 0,5 | 1,1 | 0,4 |
| Alcaldías (% pob.) | 4,8 | 5,2 | 15,4 | 2,5 | 17.8 | 1,5 | 1,6 | 19,8 | 6,0 |
| Concejalías (% pob.) | 92,6 | 78,7 | 308,8 | 102,2 | 336.0 | 35,3 | 80,1 | 201,1 | 94,3 |
| Exc. cuidado familiares (% ocu.) | 0,6 | 0,6 | 0,4 | 0,3 | 1.2 | 1,6 | 2,3 | 1,4 | 0,7 |
| Exc. cuidado de hijos (% ocu.) | 2,9 | 4,9 | 2,4 | 1,2 | 25.3 | 5,2 | 6,2 | 11,8 | 5,0 |
| Prestación maternidad (% ocu.) | 35,2 | 34,2 | 39,9 | 29,8 | 34.1 | 36,1 | 41,4 | 38,2 | 35,9 |
| Parc. Cuidado de hijos (% tasa) | 5,0 | 6,1 | 4,5 | 4,5 | 8.1 | 4,5 | 5,8 | 7,1 | 7,0 |

**Notas:** todas las variables se refieren a la población de mujeres. La variable de educación y las variables de poder político están expresadas como número de mujeres sobre la población de mujeres mayor de 18 años. La variable de puestos de dirección y las variables de excedencias y prestaciones están expresadas sobre el número de mujeres ocupadas.
**Fuente:** elaboración propia.

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Articles

# Cluster mapping in Spain: Exploring the correlation between industrial agglomeration and regional performance

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## Abstract:

This paper presents a quantitative cluster mapping methodology for traded industries, adapted for the Spanish case; also explores the correlation between the existence of clusters and regional performance. The study is made at NUTS-2 level, and a total of forty-seven out of eighty-eight 2-digits codes for CNAE-2009 are analyzed; ICT Index and Industry 4.0 Index are also designed and computed. A six-step methodology is applied departing from cross-industry linkages and implementing clustering algorithms; one set of clusters is elected and mapped over territory. The correlation analysis shows that a high number of clusters based on absolute employment data is positively correlated with variables associated with competitiveness, education, ICT adoption, and Industry 4.0, while no significant correlation is found for GDP per capita nor earning per worker.

**Keywords:** Cluster analysis; agglomeration economics; Industry 4.0; classification methods; industrial agglomeration.
**JEL Classification:** O18; R12; O52.

## Mapeo de clústers en España: Explorando la correlación entre la aglomeración industrial y el desempeño regional

## Resumen:

Esta investigación presenta una metodología cuantitativa para el mapeo de clústers en España; también explora la correlación entre la existencia de dichos clústers y el desempeño regional. El estudio se realiza a nivel NUTS-2, y se analizan un total de cuarenta y siete códigos CNAE-2009; asimismo se diseñan y calculan el índice TIC y el índice Industria 4.0. Se aplica una metodología de seis pasos basada en vínculos interindustriales y en un análisis clúster; se selecciona un grupo de clústers y se mapea sobre el territorio. El análisis de correlación muestra que un alto número de clústers basado en datos absolutos de empleo está positivamente relacionado con variables asociadas a la competitividad, educación, adopción de las TIC e Industria 4.0, mientras que no se encuentra correlación significativa con el PIB per cápita ni con las ganancias por trabajador.

**Palabras clave:** Análisis clúster; economías de la aglomeración; Industria 4.0; métodos de clasificación; aglomeración industrial.
**Clasificación JEL:** O18; R12; O52.

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## 1. Introduction

The relevance of industrial agglomeration is undeniable in a highly competitive and complex economy, in which productivity and innovation are key elements looking constantly for fertile ground to flourish (Yelkikalan et al., 2012). Additionally, urbanization and localization have proven to be an essential condition for economic development in the long term (Jofre-Monseny et al., 2014).

There are multiple models of industrial agglomeration. However, the industrial district (Becattini, 1990) and the industrial cluster (Porter, 1990) have been particularly popular for the last three decades, while the former has reached high levels of institutionalization in Europe and US (Ortega-Colomer et al., 2016).

The efforts for empirically identifying such agglomerations over territory have led to the development of mapping tools, as an effort to help policy makers, industrials, and practitioners to understand and capitalize the industrial agglomeration phenomenon. The largest institutional efforts in this matter are the Cluster Mapping Project directed by the Institute of Competitiveness (US), and the European Cluster Collaboration Platform sponsored by the European Observatory for Clusters and Industrial Change (Europe). There are also national efforts for mapping industrial districts departing from manufacturing industries (Lorenzini & Lombardi, 2018).

However, while the Cluster Mapping Project departs from Cluster Category Definitions (CCD)[1] derived from an empirical methodology designed to identify cross-industry linkages across the US economy, the European Observatory for Clusters departs from the homologation of US cluster definitions for the European context (Ketels & Protsiv, 2021; Szanyi et al., 2010), assuming industrial and environmental heterogeneity between EU countries and US (Brodzicki, 2010). Moreover, the mapping of industrial districts relies on Local Labor Markets (LLM) as territorial units (Boix & Trullén, 2010), which are not harmonized for all European countries.

This represents a relevant gap in the literature for Europe, since a comprehensive cluster mapping initiative should develop a quantitative methodology based on common data, methodology, and literature, capable of being implemented in a comprehensive way across any particular economy to identify specific CCD for the geographic region being analyzed (Ketels, 2017).

Is it possible to complement the existing efforts of cluster mapping at a national level through the implementation of a comprehensive and quantitative methodology using domestic raw data? This paper pretends to tackle that research question testing the methodology of Delgado et al. (2016) over Spain, not only because such country has been object of multiple institutional efforts to implement industrial agglomeration policies (Ortega-Colomer et al., 2016), but also because there are previous exercises of industrial agglomeration mapping that suggest sufficient data for the analysis (Boix & Galletto, 2009). Furthermore, Spain brings the opportunity to test the methodology in a country with different geographical and industrial structure when compared to other advanced economies like US and Germany (ICEX España Exportación e Inversiones, n.d.)

Since this is the first time such methodology is fully applied using domestic raw data outside US, the paper aims to: (I) present a robust cluster analysis methodology for the Spanish context to create domestic CCD and a cluster map; (II) discuss the methodological implications of the research and its differences with other exercises of cluster identification; and (III) explore the correlation between the existence of clusters and multiple economic variables. Besides, two indexes are built to summarize the regional adoption of ICT (ICT Index) and the regional adoption of technologies associated to Industry 4.0 (Industry 4.0 Index); this is the first time such regional analysis is made for Spain, helping to fill another gap in literature.

The remainder of the paper is structured as follows. The first section presents a theoretical background for the industrial cluster concept, common methodologies for cluster mapping, and externalities of this phenomenon. The second section of the article presents the quantitative methodology

[1] In the context of cluster mapping initiatives, a Cluster Category Definition is a brief description of a group of industries that share different linkages related to employment, know-how, and value-chain, among others.

implemented for the cluster mapping exercise. The third and fourth parts present results and discusses them in the frame of previous research, respectively. Finally, main conclusions and limitations are presented, together with implications for cluster scholars and policymakers.

## 2. Theoretical background

Academics make broad efforts to consolidate empirical and theoretical literature about industrial agglomeration, its causes, identification, and effects. However, for the last thirty years, the concept of industrial cluster has reached a high level of popularity and institucionalization around the world, becoming a central element for industrial policy and creating a common language for regional development that could not be matched by other related concepts (Babkin et al., 2017; Hermans, 2021; Ortega-Colomer et al., 2016; Skokan & Zotyková, 2014).

In the next paragraphs, the paper presents literature framed by previous research about the industrial cluster, its externalities, and mapping methodologies.

### 2.1. The industrial cluster concept

Although the seminal work of Marshall (1920) laid the foundations of the cluster concept, it did not reached relevance among researchers and policy makers until the 90's, influenced mainly by the research of Becattini (1990), Krugman (1991), and Porter (1990).

Since then, this idea has been evolving from the basic viewpoints of networking and competitiveness to most complex and multidisciplinary approaches like knowledge management and the triple helix of innovation (Caloffi et al., 2018). Moreover, the cluster has adopted ideas or even competed with other models of industrial agglomeration; such is the case of the industrial district concept, from which the industrial cluster adopted its socio-economic and geographical notion (Sforzi, 2015).

In its current form, the industrial cluster concept rests on geographical, economic, competitive, and sociologic foundations (Jofre-Monseny et al., 2014) (Figure 1). Furthermore, literature reveals that the historical foundations also play a relevant role in the cluster genesis and evolution when studied under the path-dependence model (Elola et al., 2012; Zhu & Pickles, 2016).

Therefore, industrial clusters can be defined as groups "of companies and institutions geographically concentrated, whose relationships have as main characteristics the collaboration and exchange of resources, which implies a high cognitive proximity among actors" (Tavares et al., 2021, p 193).

Finally, although there are multiple definitions for the cluster, all of them fit the idea of a geographic space where economics of agglomeration manifest themselves among related organizations (Delgado et al., 2016).

**Figure 1.**
**Foundations of the industrial cluster concept**

| Geographic closeness | | |
|---|---|---|
| Economics | Competitiveness | Sociology/History |
| • Input-output linkages.<br>• Labor market pooling.<br>• Knowledge spillovers. | • Cost of economic factors.<br>• Demand conditions.<br>• Strategy and rivalry in the industry.<br>• Support organizations.<br>• Economic policies. | • Path dependence.<br>• Social context and networking.<br>• Legal framework.<br>• Luck.<br>• Mutual confidence and reciprocity. |

**Source:** Authors' elaboration based on reviewed literature.

## 2.2. The externalities of industrial clusters

The conceptual heterogeneity of clusters, added to the difficulty to establish their geographic delimitations and fully identify valuable networks and participants, makes it difficult for researchers to generalize empirical findings about the impact of clusters on economic development. Skokan and Zotyková (2014) raise the next question as one of the most important for the study of clusters: how to measure the benefits of clusters on economy?

The most influential studies about the positive impact of clusters on economy are focused on innovation (Delgado, Porter, et al., 2014; Tavares et al., 2021; Ybarra & Domenech-Sanchez, 2012), showing that the access of cluster members to specialized inputs, skilled labor, market intelligence, and supportive infrastructure, has a positive effect on such variable.

Likewise, there are empirical evidence about positive externalities related to the improvement of competitiveness, productivity, salaries, unemployment, and GDP. Slaper et al. (2018) found that regions with high prevalence of industrial clusters outperformed regions with low prevalence of them in variables like GDP per capita, wage level and total income per worker. Similarly, Babkin et al. (2018) observed a positive and significant relation between the existence of industrial agglomeration phenomena and competitiveness.

Empirical studies also show that clusters, as innovation networks, enhance collaboration among government, industry, and research centers, creating more stable and less uncertain business environments in which digital transformation and Industry 4.0 have better probabilities to evolve and improve the innovation capabilities (Babkin et al., 2018; Fernandez-Escobedo et al., 2023; Götz & Jankowska, 2017; Grashof et al., 2021; Jasinska & Jasinski, 2019; Vlaisavljevic et al., 2020). Furthermore, research made on different models of industrial agglomeration has reached similar results (Hervás-Oliver, 2021).

However, the conclusions about cluster externalities are far for being definitive. Research shows that the life-cycle stage of clusters moderates the externalities of such agglomeration phenomenon (Elola et al., 2017; Skokan & Zotyková, 2014). Additionally, studies have shown that clusters can fall into technological lock-in, affecting the competitiveness of regions and industries (Elola et al., 2012; Zhu & Pickles, 2016). The best-known negative externality is what some authors call congestion costs, which implies the cost increase of key resources for cluster members, provoking diminishing returns and hurting entrepreneurship, competitiveness, and firm performance (Delgado, Porter, et al., 2014; Grashof & Fornahl, 2021; Slaper et al., 2018).

To conclude, it is important to mention that despite the challenges found by researchers to assess the effects of industrial clusters on economy and their actors, the findings about the positive effect on innovation and productivity tend to be more consistent in clusters that involve high-tech and traded industries, compared with low-tech and local industries (Bathelt & Li, 2014; Grashof & Fornahl, 2021; Slaper & Ortuzar, 2015; Tavares et al., 2021).

## 2.3. Methodologies for identification of industrial clusters

Researchers have developed multiple tools and approaches to build methodologies for clusters identification. Between the top-down methods and the bottom-up methods, the former fit better the needs of cluster mapping initiatives (Hermans, 2021; Ketels, 2017) as those methods have a quantitative approach based on statistical modeling, and are broadly applicable with nationwide/multi-industry scope.

The top-down methods depend on the definition of specific territories (spatial units for study); once studies define such units, the methodologies aim to analyze data in search of geographical concentration of industries and cross-industry linkages.

The main tools for identifying industrial agglomeration are the indexes and location quotients (LQ). Ellison et al. (2010) proposed an index of industry concentration which have suffered from multiple revisions and adaptations for cluster mapping projects; similarly, the Gini coefficient is another index adapted to measure industrial agglomeration (Burki & Khan, 2011). The LQ is also a popular measure to explore agglomeration; this one revolves around the employment specialization of regions when compared with others (Slaper et al., 2018). The central limitation of those tools is that they only can be used on well specified industries or group of industries, which make them useless to find cross-industry linkages.

In the case of cross-industry linkages identification, there are tools and methodologies that depart from Marshallian micro-foundations of agglomeration; among them, it is worth mentioning the next ones.

The quantitative input-output analysis (QIOA) was developed to capture linkages related to flow of goods and services, departing from the study of Input-Output matrices (Oosterhaven et al., 2001; Titze et al., 2011). Similarly, the cross-industry patent citations measures and technology-flow matrices were developed to identify agglomeration patterns for knowledge linkages among industries (Ellison et al., 2010; Scherer, 1984). These tools are commonly limited for the availability of the data and the disaggregation level of it.

Most robust methodologies include the locational correlation (LC) analysis and the Sforzi-ISTAT methodology. The first one is capable of combining multiple approaches and capturing cross-industry linkages related to co-location, labor market pooling, input-output relations, and knowledge-flow, and it is the base of contemporaneous cluster mapping efforts (Diodato et al., 2018). However, it is limited for the quality/quantity of the data and is not capable of finding agglomeration patterns by itself. The second one is based on industrial district's literature and departs of the identification of LLM and the definition of the groups of economic activities, which should be made previous to the analysis (Boix & Galletto, 2009). Nevertheless, while the methodology can find agglomeration patterns, it is limited by the need of a harmonized LLM structure for different countries and the ex ante aggregation of industries, which reduces its flexibility and its capacity to find complex cross-industry linkages.

Finally, state-of-the-art methodologies combine multiple of these methods with algorithms of cluster analysis based on Ward's linkage, finding agglomeration patterns and cross-industry linkages at the same time, providing the needed data to create appropriate CCD for specific territories (Delgado et al., 2016). Unfortunately, such methodologies tend to use administrative divisions as spatial units for study, missing the rationale of community that shapes the concept of LLM, which is at the heart of the industrial district mapping (Canello & Pavone, 2016).

Although the presented tools and methods have the mentioned limitations, researchers recognize their valuable potential for cluster mapping, particularly when they are combined, and their results are used for comparison purposes.

## 3. Methodology

This empirical research has an exploratory, descriptive, non-experimental, and cross-sectional design with a quantitative approach, using the statistical technique known as cluster analysis. The research also uses the Pearson correlation coefficient to explore correlation between pairwise industries, and among CCD and multiple macroeconomic variables.

The presented methodology is focused on traded industries (Delgado, Bryden, et al., 2014) and based on the work of Delgado et al. (2016) which describes the current algorithm used by the Cluster Mapping Project to establish CCD in US.

The analysis is based on the statistical classification of economic activities for Spain (known as CNAE-2009) at 2-digits level and uses autonomous communities as spatial units to analyze data (NUTS-2), excluding Ceuta and Melilla. These decisions are made for two reasons: first, to avoid as much as possible data suppression from the Spanish Statistical Office; and second, to avoid finding artificially high LC across many industries if small regions with low industrial representations are used (Porter, 2003).

The method follows multiple steps: to build the datasets which are arranged as similarity matrices (step one); to build and assess the groups of clusters (steps second to fourth); and to choose the highest quality group of clusters and project it over Spanish territory (steps five and six).

### 3.1. Data and sources

This research uses multiple open databases from the Spanish Statistical Office, the Spanish Patent and Trademark Office, and the European Commission[2].

A total of 47 out of 88 2-digits codes for CNAE-2009 are analyzed[3]. The first group of data used for cluster analysis includes:

- Statistical structure for business – commerce, industry, and services (year 2019, CNAE-2009 2-digits, NUTS-2).
- Annual national accounting – input-output matrix (year 2016 – rev. 2019).
- Annual national accounting – origin-destination matrices (years 2010 to 2018).
- The labor force survey (year 2011, CNO-2011 2-digits, CNAE-2009 2-digits).

The second group of data is used to explore correlation between CCD and macroeconomic variables, and includes:

- For economic development:
  - The regional accounting for the real GDP per capita (year 2019).
- For population and employment:
  - The labor force survey for regional active population and for regional unemployment rate (average for all four quarters of 2019).
  - The wage structure survey for total income per worker (year 2019).
  - The educational attainment survey for adults with professional education or more (year 2016).
- For innovation:
  - The regional patent application per million inhabitants as innovative activity (average 2018-2019).
- For competitiveness:
  - The Regional Competitiveness Index (RCI) for sub-index "basic" (year 2019).
- For ICT and Industry 4.0:
  - The regional survey on the use of Information and Communication Technologies (ICT).
  - eCommerce in enterprises with more than ten employees (years 2017, 2019, 2020 and 2021, depending on the specific item since different data is collected each year).

### 3.2. Step one: Building the similarity matrices

Similarity matrices $M_{ij}$ provide information about the relatedness between pairs of industries *i* and *j*. To build a unidimensional matrix, it is required to transform one or more indicators into a single

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[2] Data were retrieved from https://www.ine.es for economy, labor market and ICT; http://consultas2.oepm.es/ipstat/faces/IpsBusqueda.xhtml for industrial property, and https://ec.europa.eu/regional_policy/es/information/maps/regional_competitiveness/ for competitiveness.

[3] Information for 21 codes was not available by the Spanish Statistical Office; another 31 codes were grouped into 11 provisional codes to homologize the CNAE-2009 with the industrial classification of the input-output matrix. Due to statistical confidentiality, there is incomplete information for specific industries in particular regions; this data was disregarded.

similarity measure; multidimensional matrices are built combining similarity measures from unidimensional matrices.

The indicators and measures used in this research are chosen to capture as many cross-industry linkages as possible (e.g., knowledge, skills, supply, or demand links). Table 1 shows the specifications of each matrix built.

**Table 1.**
**Similarity matrices used to generate sets of CCDs**

| Similarity matrix | Indicators used | Measure computed |
|---|---|---|
| **Unidimensional matrices** | | |
| Co-location pattern for employment (LC_Emp) | Employment size of industry *i* and *j* in region *r* | Locational correlation of employment [-1, 1] |
| Co-location pattern for establishments (LC_Est) | Establishments of industry *i* and *j* in region *r* | Locational Correlation of establishments [-1, 1] |
| Geographic concentration of employment (COI) | Employment size of industry *i* and *j* in region *r* | Co-agglomeration Index |
| Input-Output Links (IO) | Inputs of industry *i* coming from *j*, and outputs of industry *i* going to *j* | Average share of inputs of industry i coming from j, outputs of industry i going to j, and vice versa [0, 1] |
| Labor Occupation Links (Occ) | Employment size of industry *i* and *j* related to occupation *k* | Occupational correlation [-1, 1] |
| **Multidimensional matrices** | | |
| Co-location pattern (LC) | Locational correlation of employment, and locational correlation of establishments | Average of LC_Emp and LC_Est |
| Co-location pattern and Geographic concentration of employment (LC_COI) | Locational correlation of employment, locational correlation of establishments, and Co-agglomeration Index | Average of (standardized) LC_Emp, LC_Est, and COI |
| Geographic concentration of employment, Input-Output Links, and Labor Occupation Links (COI_IO_Occ) | Co-agglomeration Index, average share of input-output links, and occupational correlation | Average of (standardized) COI, IO, and Occ |
| All unidimensional measures (ALL) | All unidimensional measures | Average of (standardized) LC_Emp, LC_Est, COI, IO, and Occ |

**Source:** Authors' elaboration.

### 3.3. Step two: Identifying traded industries and adjusting similarity matrices

While local industries serve local markets, traded industries are those that produce goods and services that are either exported or sold across regions. Since this research is focused on traded industries (both natural-resource-based and not), it is necessary to identify them and remove local ones from the similarity matrices.

A multi-criterion methodology is applied to assess the 47 CNAE-2009 2-digit industries and find traded industries. For this multi-criterion methodology, the set of traded industries includes all those industries classified as traded by both the gross value-added ratio methodology and the locational Gini Coefficient methodology:

- The export to gross value-added ratio (Mano & Castillo, 2015), based on a single cutoff set by literature, using the average of 2010-to-2018 ratios to reduce overrepresentation of external shocks.
- The locational Gini Coefficient (Carlino & Kerr, 2015), based on a single cutoff set by authors of this research.

## 3.4. Step three: Setting parameters and running clustering functions

In this step, the following parameters (*β*) are used: clustering functions are run over raw data as each similarity matrix is built with a common internal scale; starting values for clustering functions are chosen at random; and multiple number of clusters (*numc*) are set, going from seven to 13[4], when functions are run.

Two clustering functions (*F*) for continuous data are used in this research (Delgado et al., 2016; Everitt et al., 2011; Grimmer & King, 2011): the hierarchical function of Ward's minimum variance (squared Euclidean distance) (*H*), and the centroid based function (kmean) (*K*).

Before running clustering functions over the similarity matrices, the algorithm is tested and validated following the method of Delgado et al. (2016), using an artificial similarity matrix based on the first digit of the CNAE-2009 2-digits code for the traded industries.

Let *C* be a single group of clusters given *F* and β, then:

$$C = F\left(M_{ij}, \beta\right) \tag{1}$$

The clustering algorithm is run over all nine similarity matrices, using all possible combinations of parameters.

## 3.5. Step four: Assessing quality of *C*s through Validation Scores

Validation Scores (*VS*) are computed for each *C*, following Delgado et al. (2016) methodology; *VS* are the average of two partial validations scores*: VS-Cluster* and *VS-Industry*. All five unidimensional matrices *Mij* are used to build the validation scores, since the capture of different industry interdependencies is assumed for each of them; a single similarity measure between *i* and *j* represents a relatedness measure.

On the one side, *VS-Cluster* measures whether individual clusters (*c*) in *C* are meaningfully different from each other, and it is made up of two averaged sub-scores. These sub-scores depart from the Within Cluster Relatedness for *c* ($WCR_c$) measure (as the average relatedness between pairs of industries within a *c*), and the Between Cluster Relatedness for *c* ($BCR_c$) measure (as the average relatedness between industries in *c* and those in another cluster). *VS-Cluster*'s sub-scores are expressed as follows:

$$VS - Cluster\ Average_C^M = \frac{\sum_c I[WCR_c(M_{ij}) > AvgBCR_c(M_{ij})]}{N_c} * 100 \tag{2}$$

$$VS - Cluster\ Percentile95_C^M = \frac{\sum_c I[WCR_c(M_{ij}) > Pctile95BCR_c(M_{ij})]}{N_c} * 100 \tag{3}$$

where $N_c$ is the number of clusters in *C,* and *I* is an indicator function equal to 1 for a given cluster *c* which met the condition expressed inside brackets.

On the other hand, *VS-Industry* measures whether individual industries (*i*) in *C* are more related to the industries within its own *c* than to industries outside its cluster, and it is also made up of two averaged

[4] As the analysis is based on CNAE-2009 2-digits codes with 27 traded industries, working with numbers of clusters greater than 13 would have increased the chances for the appearance of multiple one-industry groups; the minimum number of clusters is set following to Delgado et al. (2016) who set the minimum number of clusters as the half of the maximum number chosen.

sub-scores. These sub-scores depart from the Within Cluster Relatedness for $i$ in $c$ ($WCR_{ic}$) measure (as the average relatedness between $i$ and other industries within a $c$), and the Between Cluster Relatedness for $i$ in $c$ ($BCR_{ic}$) measure (as the average relatedness between $i$ and those in another cluster). *VS-Cluster*'s sub-scores are expressed as follows:

$$VS - Industry\ Average_C^M = \frac{\sum_i I[WCR_{ic}(M_{ij}) > AvgBCR_i(M_{ij})]}{N_i} * 100 \tag{4}$$

$$VS - Industry\ Percentile95_C^M = \frac{\sum_i I[WCR_{ic}(M_{ij}) > Pctile95BCR_i(M_{ij})]}{N_i} * 100 \tag{5}$$

where $N_i$ is the number of industries in $C$.

## 3.6. Step five: Choosing the *C*s with higher quality and setting CCD

The $C$ with the highest position in the *VS* rank (let us call it $C^*$) is elected to create CCD at the regional level (NUTS-2). CCD are defined arbitrarily for each $c$, looking at the industries which configure each cluster and aiming to suggest names easy to assimilate for researchers, policy makers, and development practitioners.

## 3.7. Step six: Finding the territorial presence of clusters over Spain

Since each $C$ is configured by a set of $c$s, this step is about finding the presence of each $c$ over the analyzed regions (spatial units of study).

The US's Cluster Mapping Project recognizes three types of clusters presence over territory based on employment share and location quotients (Delgado et al., 2016; Ketels, 2017): clusters by top employment specialization (TESp), clusters by top employment share (TESh), and clusters by top employment specialization & share (TESS). The results of the analysis of territorial presence are presented in the Results section.

## 3.8. The correlation analysis

Finally, after exploring the territorial presence of $c$, correlation analysis is made among cluster presence and multiple variables.

The presence of each $c$ over regions is arranged as a discrete dichotomous variable (1-0, the cluster is present or not). Also, the total count of $c$ (by TESp, TESh, and TESp) in each territory is considered.

Multiple variables are selected to run the Pearson's correlation analysis against the presence of clusters. Variables election is based on the work of Delgado et al. (2014) and Slaper et al. (2018); the calculation and introduction of ICT and Industry 4.0 indexes is a novelty introduced in this research. To build those Indexes, multiple measures are considered following literature about ICT and Industry 4.0 impact on business (Almeida et al., 2020; Atik & Ünlü, 2019; Maresova et al., 2018).

On the one hand, the ICT Index groups ten different measures related to the use of computers, Internet connection, webpage, social networks, ERP, CRM, electronic communications, eGovernment, eSignature, and cybersecurity. On the other hand, the Industry 4.0 Index groups six different measures related to the use of: industrial robots, big data, cloud computing, 3D printing, Internet of things, and artificial intelligence. The grouping methodology for both indexes is based on the World Economic Forum (WEF) (Atik & Ünlü, 2019).

It is also relevant to point out that for competitiveness the RCI basic sub-index is chosen due to the full RCI is configured also by another two sub-indexes (efficiency and innovation) which are highly correlated with other variables chosen for this research, such as population, educational attainment, innovation activity and ICT adoption.

Correlations are presented in the Results section.

## 4. Results

Descriptive statistics are obtained for each similarity matrix (Table 2). The correlation among all the similarity matrices seems to be significant at 1% level, except for Occ with LC_Emp, LC_Est, and LC.

**Table 2.**
**Descriptive statistics for similarity matrices; 47 industries (CNAE-2009 2-digits codes) and N=2,167**

| Similarity Matrices $M_{ij}$ | Mean | Median | Std. Dev. | Min. | Max |
|---|---|---|---|---|---|
| LC_Emp | 0.672 | 0.767 | 0.300 | -0.540 | 1.000 |
| LC_Est | 0.743 | 0.822 | 0.265 | -0.914 | 0.998 |
| COI | -0.001 | 0.000 | 0.021 | -0.089 | 0.136 |
| IO | 0.014 | 0.007 | 0.023 | 0.000 | 0.343 |
| Occ | 0.130 | 0.050 | 0.220 | -0.128 | 0.973 |
| LC | 0.708 | 0.782 | 0.267 | -0.658 | 0.999 |
| LC_COI | -0.029 | 0.150 | 0.780 | -3.962 | 2.613 |
| COI_IO_Occ | -0.074 | -0.169 | 0.530 | -1.403 | 2.847 |
| ALL | -0.053 | 0.018 | 0.548 | -2.186 | 1.876 |

**Note:** An observation is any pair of industries (*ij*, $i \neq j$). All unidimensional matrices are based on 2019 data except for IO and Occ, which is based on 2016 and 2011 data, respectively.
**Source:** Authors´ elaboration.

Using the similarity matrices, a single set of traded industries is configured (Table 3), meeting two key attributes: the exclusion of industries that conceptually are classified as local (e.g., real state, retail, local transportation, and sewerage), and the improving of the correlation between similarity matrices of traded industries when compared with correlation between similarity matrices for all industries. 27 out of 47 industries are categorized as traded.

The cluster algorithm is applied over the nine similarity matrices of traded industries, and 126 *Cs* are obtained (the number is equal to all combinations among *F,* β and $M_{ij}$). The quality of individual *Cs* is assessed through the *VS* (Table 4).

**Table 3.**
**List of 27 out of 47 CNAE-2009 2-digit codes classified as traded industries**

| Code | Description |
|---|---|
| IN05 | Groups: Mining of coal and lignite; Extraction of crude petroleum and natural gas; Mining of metal ores; Other mining and quarrying; Mining support service activities |
| IN10 | Groups: Manufacture of food products; Manufacture of tobacco products |
| IN13 | Groups: Manufacture of textiles; Manufacture of wearing apparel; manufacture of leather and related products |
| IN16 | Manufacture of wood and of products of wood and cork, except furniture; mfg. of articles of straw and plaiting materials |
| IN17 | Manufacture of paper and paper products |
| IN19 | Manufacture of coke and refined petroleum products |
| IN20 | Manufacture of chemicals and chemical products |
| IN21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| IN22 | Manufacture of rubber and plastic products |

**Table 3. cont.**
**List of 27 out of 47 CNAE-2009 2-digit codes classified as traded industries**

| Code | Description |
|---|---|
| IN23 | Manufacture of other non-metallic mineral products |
| IN24 | Manufacture of basic metals |
| IN25 | Manufacture of fabricated metal products, except machinery and equipment |
| IN26 | Manufacture of computer, electronic and optical products |
| IN27 | Manufacture of electrical equipment |
| IN28 | Manufacture of machinery and equipment n.e.c. |
| IN29 | Manufacture of motor vehicles, trailers, and semi-trailers |
| IN30 | Manufacture of other transport equipment |
| IN31 | Groups: Manufacture of furniture; Other manufacturing |
| IN50 | Water transport |
| IN51 | Air transport |
| IN58 | Publishing activities |
| IN59 | Groups: Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities |
| IN61 | Telecommunications |
| IN62 | Groups: Computer programming, consultancy, and related activities; Information service activities |
| IN72 | Scientific research and development |
| IN73 | Advertising and market research |
| IN79 | Travel agency, tour operator and other reservation service and related activities |
| | **Traded Industries to Total Industries ratio**<br>**57.4%** |

**Source:** Authors´ elaboration.

TABLE 4.
**Validation scores (*VS*), partial validation scores (*VS-Cluster* and *VS-Industry*) and sub-scores (VS-Cluster Avg, VS-Cluster Pctile95, VS-Industry Avg, VS-Industry) for the ten highest-ranked groups of clusters (*C*s)**

| Rank (*VS*) | *VS* | Method | Similarity Matrix $M_{ij}$ | Numc | *C* code | Rank (VS-Cluster) | VS-Cluster | VS-Cluster Avg | VS-Cluster Pctile95 | Rank (VS-Industry) | VS-Industry | VS-Industry Avg | VS-Industry Pctile95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 72.9 | H | ALL | 7 | H-ALL-7 | 4 | 72.9 | 80.0 | 65.7 | 1 | 73.0 | 90.4 | 55.6 |
| 2 | 72.6 | K | COI_IO_Occ | 8 | K-COI_IO_Occ-8 | 1 | 76.3 | 85.0 | 67.5 | 3 | 68.9 | 88.9 | 48.9 |
| 3 | 71.6 | H | COI_IO_Occ | 7 | H-COI_IO_Occ-7 | 2 | 74.3 | 88.6 | 60.0 | 3 | 68.9 | 88.9 | 48.9 |
| 4 | 70.3 | K | COI_IO_Occ | 7 | K-COI_IO_Occ-7 | 3 | 72.9 | 74.3 | 71.4 | 5 | 67.8 | 83.7 | 51.9 |
| 5 | 66.6 | K | Occ | 7 | K-Occ-7 | 4 | 72.9 | 94.3 | 51.4 | 17 | 60.4 | 91.1 | 29.6 |
| 6 | 64.8 | K | COI_IO_Occ | 9 | K-COI_IO_Occ-9 | 7 | 63.3 | 75.6 | 51.1 | 7 | 66.3 | 87.4 | 45.2 |
| 7 | 63.3 | K | ALL | 9 | K-ALL-9 | 9 | 58.9 | 64.4 | 53.3 | 4 | 67.8 | 84.4 | 51.1 |
| 8 | 62.4 | H | COI | 9 | H-COI-9 | 8 | 60.0 | 71.1 | 48.9 | 10 | 64.8 | 85.2 | 44.4 |
| 9 | 62.3 | H | Occ | 7 | H-Occ-7 | 5 | 67.1 | 88.6 | 45.7 | 23 | 57.4 | 87.4 | 27.4 |
| 10 | 62.1 | K | ALL | 7 | K-ALL-7 | 13 | 57.1 | 65.7 | 48.6 | 6 | 67.0 | 86.7 | 47.4 |

**Notes:** Rank shows the relative position of *C* compared with the others when considering the relevant score. For *VS-Cluster* and *VS-Industry* some scores are equal, so the ranks are too. H and K represent the clustering function used (hierarchical and kmean, respectively).
**Source:** Authors´ elaboration.

**Table 5.**
**Cluster Category Definitions (CCD) and list of industries (by code) configuring each cluster c for *C****

| *c* number | CCD | Industry codes |
|---|---|---|
| 01 | Extraction, mining, and agro-industrial cluster | IN05 |
| | | IN10 |
| | | IN16 |
| | | IN23 |
| | | IN31 |
| 02 | Packaging, covers and lining – manufacturing cluster | IN13 |
| | | IN17 |
| | | IN20 |
| | | IN22 |
| 03 | Fuel and multipurpose vehicles – manufacturing cluster | IN19 |
| | | IN30 |
| 04 | Biotechnological cluster | IN21 |
| | | IN26 |
| | | IN72 |
| 05 | Electromechanical and automotive cluster | IN24 |
| | | IN25 |
| | | IN27 |
| | | IN28 |
| | | IN29 |
| 06 | Water-travel cluster | IN50 |
| 07 | Tourism, ICT, and creativity – services cluster | IN51 |
| | | IN58 |
| | | IN59 |
| | | IN61 |
| | | IN62 |
| | | IN73 |
| | | IN79 |

**Source:** Authors' elaboration.

The presence of clusters in regions is presented in Table 6, distinguishing among clusters presence by top employment specialization (TESp), by top employment share (TESh), and by top employment specialization & share (TESS). As shown, Catalonia stands out reaching the maximum number of clusters by TESh. Contrastingly, the number of clusters by TESp is more evenly distributed among regions. Besides, the number of clusters by TESS is smaller since it combines both previous criteria.

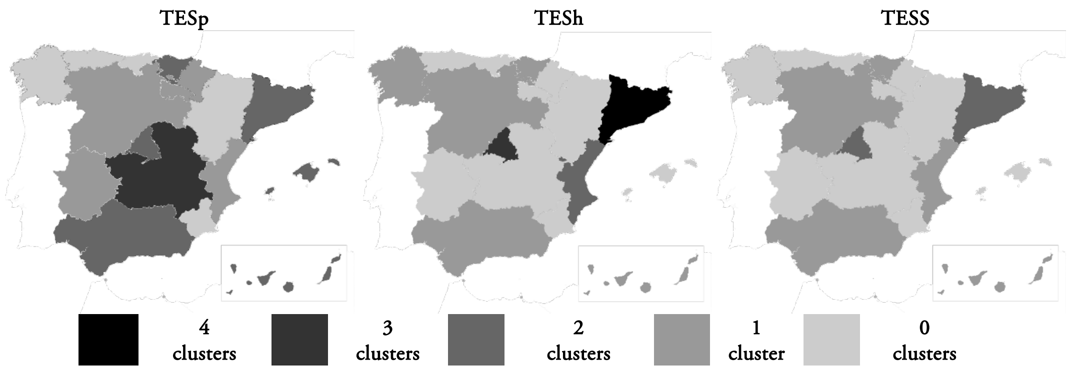
**Table 6.**
**Clusters presence by autonomous community (C* set)**

| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | TESp | TESh | TESS |
|---|---|---|---|---|---|---|---|---|---|---|
| Andalusia | | | *** | | | | * | 2 | 1 | 1 |
| Aragon | | | | | | | | 0 | 0 | 0 |
| Asturias, Principality of | | | | | | | | 0 | 0 | 0 |
| Balearic Islands | | | | | | * | * | 2 | 0 | 0 |
| Basque Country | | | * | | *** | | | 2 | 1 | 1 |
| Canary Islands | | | | | | *** | * | 2 | 1 | 1 |
| Cantabria | | | | | | | | 0 | 0 | 0 |
| Castile and León | *** | | | | | | | 1 | 1 | 1 |
| Castilla – La Mancha | * | * | * | | | | | 3 | 0 | 0 |
| Catalonia | | *** | | *** | ** | | ** | 2 | 4 | 2 |
| Extremadura | * | | | | | | | 1 | 0 | 0 |
| Galicia | ** | | | | | | | 0 | 1 | 0 |
| Madrid, Community of | | | ** | *** | | | *** | 2 | 3 | 2 |
| Murcia, Region of | | | | | | | | 0 | 0 | 0 |
| Navarre, Ch. Community of | | | | | * | | | 1 | 0 | 0 |
| Rioja, La | | * | | | | | | 1 | 0 | 0 |
| Valencian Community | | *** | | | | ** | | 1 | 2 | 1 |
| **Total** | | | | | | | | **20** | **14** | **9** |

**Note:** The table distinguish clusters presence by top employment specialization (TESp) (*), by top employment share (TESh) (**), and by top employment specialization & share (TESS) (***).
**Source:** Authors´ elaboration.

Multiple maps can be drawn departing from the result of this research. For example, **Figure 2** shows the intensity of clusters presence by TESp, TESh, and TESS over regions; it draws attention that regions with high population concentration show a high presence of industrial clusters.

**Figure 2.**
**Intensity of clusters presence by TESp, TESh, and TESS over autonomous communities (based on *C**)**




**Source:** Authors´ elaboration.

Finally, descriptive statistics are obtained for variables classified as economic development, population and employment, innovation, competitiveness, ICT, and Industry 4.0 (Table 7). ICT Index shows positive and significant correlation with nine out of ten measures grouped (the correlation with social networks is positive but not statistically significant). Industry 4.0 Index shows positive and significant correlation with five out of six measures grouped (the correlation with use of industrial robots is positive but not statistically significant). Table 8 shows regional performance for both ICT Index and Industry 4.0 Index.

To conclude, full correlation matrix is computed (Table 9).

**TABLE 7.**
**Descriptive Statistics for autonomous communities' variables (N=17)**

| Categories | Variables | Mean | Median | Std. Dev. | Min. | Max |
|---|---|---|---|---|---|---|
| ECON. | GDP per capita (euros) | 24808.773 | 23197.379 | 4930.420 | 18275.749 | 34805.061 |
| | Earning per worker (euros) | 23642.193 | 22877.130 | 2627.158 | 19940.680 | 29476.210 |
| | Natural resources dependency | 0.040 | 0.043 | 0.018 | 0.012 | 0.074 |
| POP. & | Population (miles) | 2760.900 | 2038.700 | 2558.826 | 314.400 | 8448.200 |
| EMP. | % Population with a grade or more | 0.143 | 0.136 | 0.032 | 0.103 | 0.231 |
| | Unemployment rate | 0.133 | 0.118 | 0.042 | 0.082 | 0.215 |
| INNOV. | Patent application to million inhab. ratio | 29.147 | 28.500 | 15.672 | 7.000 | 66.000 |
| COMP. | RCI basic sub-index | -0.070 | -0.078 | 0.138 | -0.213 | 0.302 |
| ICT | ICT Index | 0.548 | 0.576 | 0.164 | 0.245 | 0.829 |
| IND. 4.0 | Industry 4.0 index | 0.466 | 0.435 | 0.170 | 0.212 | 0.808 |

**Source:** Authors´ elaboration.

**TABLE 8.**
**Regional ICT Index and Industry 4.0 Index**

| Region | ICT Index | Industry 4.0 Index |
|---|---|---|
| Andalusia | 0.605 | 0.373 |
| Aragon | 0.648 | 0.515 |
| Asturias, Principality of | 0.526 | 0.456 |
| Balearic Islands | 0.497 | 0.243 |
| Basque Country | 0.588 | 0.579 |
| Canary Islands | 0.332 | 0.212* |
| Cantabria | 0.245* | 0.615 |
| Castile and León | 0.454 | 0.435 |
| Castilla – La Mancha | 0.365 | 0.392 |
| Catalonia | 0.829** | 0.723 |
| Extremadura | 0.321 | 0.392 |
| Galicia | 0.604 | 0.434 |
| Madrid, Community of | 0.800 | 0.808** |
| Murcia, Region of | 0.572 | 0.349 |
| Navarre, Ch. Community of | 0.576 | 0.630 |
| Rioja, La | 0.631 | 0.226 |
| Valencian Community | 0.715 | 0.539 |

**Note:** ** Highest score. *Lowest score.
**Source:** Authors´ elaboration.

TABLE 9.
**Correlation between prevalence of clusters (C*) and selected variables (N=17).**

| | TESp | TESh | TESS | 01 | 02 | 03 | 04 | 05 | 06 | 07 | GDP per capita (euros) | Earning per worker (euros) | Natural resources dependency | Population (miles) | Share of population with a Grade or more | Unemployment rate | Patent application to million inhab. ratio | RCI basic sub-index | ICT Index | Industry 4.0 index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TESp | 1.000 | | | | | | | | | | | | | | | | | | | |
| TESh | 0.362 | 1.000 | | | | | | | | | | | | | | | | | | |
| TESS | .496* | .925** | 1.000 | | | | | | | | | | | | | | | | | |
| 01 | 0.044 | -0.156 | -0.223 | 1.000 | | | | | | | | | | | | | | | | |
| 02 | 0.345 | 0.326 | 0.176 | 0.019 | 1.000 | | | | | | | | | | | | | | | |
| 03 | .645** | 0.206 | 0.375 | 0.019 | 0.019 | 1.000 | | | | | | | | | | | | | | |
| 04 | 0.326 | .850** | .772** | -0.203 | 0.228 | 0.228 | 1.000 | | | | | | | | | | | | | |
| 05 | 0.246 | 0.339 | 0.313 | -0.257 | 0.107 | 0.107 | 0.310 | 1.000 | | | | | | | | | | | | |
| 06 | 0.246 | 0.071 | 0.091 | -0.257 | 0.107 | -0.257 | -0.169 | -0.214 | 1.000 | | | | | | | | | | | |
| 07 | .576* | .548* | .622** | -0.358 | -0.054 | 0.251 | .566* | 0.040 | 0.378 | 1.000 | | | | | | | | | | |
| GDP per capita | 0.160 | 0.416 | 0.416 | -0.405 | -0.011 | 0.208 | .568* | .603* | -0.174 | 0.169 | 1.000 | | | | | | | | | |
| Earning per worker | 0.158 | 0.343 | 0.375 | -0.461 | -0.096 | 0.364 | 0.466 | .727** | -0.284 | 0.092 | .894** | 1.000 | | | | | | | | |
| Natural resources dependency | -0.254 | -0.451 | -.571* | .709** | 0.025 | -0.189 | -0.475 | -.522* | -0.174 | -0.368 | -.66** | -.68** | 1.000 | | | | | | | |
| Population | 0.437 | .820** | .817** | -0.159 | 0.219 | 0.464 | .645** | 0.134 | 0.008 | .643** | 0.124 | 0.151 | -0.268 | 1.000 | | | | | | |
| % Population with a grade or more | 0.239 | .579* | .623** | -0.294 | -0.002 | 0.459 | .635** | 0.406 | -0.162 | 0.186 | .830** | .833** | -.64** | 0.403 | 1.000 | | | | | |
| Unemployment rate | 0.244 | -0.105 | -0.005 | 0.261 | -0.070 | 0.127 | -0.224 | -0.436 | 0.240 | 0.264 | -.79** | -.68** | 0.348 | 0.216 | -.557* | 1.000 | | | | |

**TABLE 9. CONT.**
**Correlation between prevalence of clusters (C*) and selected variables (N=17).**

| | TESp | TESh | TESS | 01 | 02 | 03 | 04 | 05 | 06 | 07 | GDP per capita (euros) | Earning per worker (euros) | Natural resources dependency | Population (miles) | Share of population with a Grade or more | Unemployment rate | Patent application to million inhab. ratio | RCI basic sub-index | ICT Index | Industry 4.0 index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Patent application to million inhab. ratio** | -0.354 | 0.079 | 0.045 | -0.398 | -0.074 | 0.008 | 0.159 | 0.351 | -0.334 | -0.282 | .593* | .577* | -.497* | 0.020 | .532* | -.62** | 1.000 | | | |
| **RCI basic sub-index** | 0.301 | .556* | .544* | -0.199 | 0.269 | 0.456 | .763** | 0.303 | -0.307 | 0.157 | .673** | .615** | -.565* | 0.359 | .764** | -0.467 | 0.441 | 1.000 | | |
| **ICT Index** | 0.057 | .662** | .543* | -0.389 | 0.304 | 0.146 | .612** | 0.339 | -0.095 | 0.264 | .592* | .505* | -.488* | .600* | .642** | -0.406 | .555* | 0.476 | 1.000 | |
| **Industry 4.0 index** | -0.017 | .593* | .518* | -0.178 | 0.014 | 0.243 | .665** | .502* | -0.379 | 0.023 | .630** | .691** | -0.456 | 0.411 | .755** | -.493* | .589* | .763** | 0.470 | 1.000 |

**Note:** *Coefficients are significant at 5% level. **Coefficients are significant at 1% level.
**Source:** Authors´ elaboration.

## 5. Discussion

This study applies for first time this methodology to the Spanish context, using raw data of the country to build specific Spanish CCD at the NUTS-2 level. Such approach separates this effort from others previously made, since they depart from CCD built for US. Moreover, the analysis is sharp enough to show the relevance of industries for specific regions, and reinforces previous findings about regional cluster presence in Spain made through case-studies (Elola et al., 2012; Jofre-Monseny et al., 2014; Molina-Morales et al., 2017; Ortega-Colomer et al., 2016; Vlaisavljevic et al., 2020). Additionally, this cluster mapping exercise groups industries using empirical measures rather than a conceptual aggregation of sectors without a robust theoretical justification, as the industrial district mapping has done before (Boix & Trullén, 2010; Canello & Pavone, 2016).

The study proves the feasibility of the application of an end-to-end methodology to map clusters in Europe, placing serious questions about why the current cluster mapping efforts assume that locational patterns found on US are representative for those found in the EU, and tend to homologate American CCD for Europe (Ketels & Protsiv, 2021). That *representativeness assumption* could not be reasonable for less-large, less-diversified, less-dynamic, and less-industrialized economies (Brodzicki, 2010). Furthermore, Delgado et al. (2016) states that current and past barriers to trade across Europe shaped different patterns of agglomeration when compared with US, and that American CCD aim to be a benchmark for other economies.

This research supports the idea that such representativeness assumption is questionable at least for the Spanish case, due to the next three reasons.

First, the spatial units of study for the American case are the *Economic Areas (EA)*, which represent regional relevant markets delimited for economic purposes. In contrast, in the EU the cluster mapping is made over administrative divisions (generally NUTS-2), which are defined by each member country following local criteria (in the case of Spain, historical and socio-political antecedents shaped the administrative divisions). This is relevant because the nature of the spatial units has an impact over the capacity of the similarity matrices to identify cross-industry linkages, and while for US the LC_Est/IO have the best performance as unidimensional matrices and COI/Occ have the worst ones, for Spain the LC_Est/IO have the worst performance and COI/Occ the best ones. Additionally, for the US case the similarity matrix with the best performance is a multidimensional one (LC_IO_Occ), and the authors never mix the LC and COI as they assume that such indicators capture similar linkages among industries. For the Spanish case that assumption is overlooked, and results show that the similarity matrix with the best performance is one constructed with the COI: the COI_IO_Occ.

Second, while this paper departs from traded industries as the study of Delgado et al. (2016) does, the three-criteria methodology to identify traded industries of the latter study is not capable to effectively discriminate by itself between local and traded industries for the Spanish case. Instead, this study applies a different multi-criterion methodology based on export to gross value-added ratio and the locational Gini Coefficient; for the last criterion, the cutoff is set at 0.01, as multiple cutoffs are tested in incremental ranges of 0.01 looking for the set of traded industries with the maximum overlap compared with the set defined by the three-criteria methodology of Delgado et al. (2014) (the geometric mean is used to measure the industry overlap in each direction).

Third, the North America's industrial classification is not harmonized with the EU's one. Therefore, the adaptation of the American CCD for Europe depends on the reinterpretation of the American industrial codes for the European case, which is not always a straightforward task (Brodzicki, 2010). Additionally, since the cluster algorithm relies on the data of individual industries, the differences on the interpretation of *what is* each industry will have a direct impact on the assessed cross-industry linkages and thus in the identified clusters.

The presented arguments support the idea that a robust and reliable cluster mapping effort must depart for locally-measured relatedness among industries. Otherwise, the adaptation of foreign CCD could disregard local cross-industry linkages and overestimate other less relevant ones. Moreover, this research also demonstrates that depending on the economy being analyzed, the methodology could require the modification or complementation of procedures, criteria, and indicators with the purpose of improving the results and meeting the conceptual requirements.

This is a call for European researchers, policy makers, and economic development practitioners to take with reservation the data about local agglomeration when it is derived from the adaptation of foreign measures for cross-industry linkages. Failing to do so could lead to deficient industrial policy design, inadequate cluster performance assessment and misinterpretation of cluster's externalities. In addition, initiatives like the European Cluster Collaboration Platform and the European Clusters Excellence program present maps that show and assess presence of *cluster organizations* and not empirical evidence of the presence of industrial clusters, which could lead to the misinterpretation of the existence of industrial clusters as a real agglomeration phenomenon and not as a policy tool.

In a different train of thought, the correlation analysis between clusters' presence and different variables also shows insightful results discussed in the next paragraphs.

The correlations presented have different responses when the clusters' presence is assessed by absolute measures than when it is assessed with relative measures. In other words, the clusters' presence measured by TESh (which departs from absolute measures of employment share for each CCD) presents more statistically significant correlations with other variables than the clusters' presence measured by TESp (which departs from relative measures of employment and establishments based in LQ). Such finding suggests that, at this level of data aggregation, the absolute employment concentration on specific industries could be more useful when exploring the effects of industrial clusters over economy.

This analysis also supports previous findings related to the correlation of clusters' presence and variables like population education level, natural resource dependency, and competitiveness, showing different levels of statistical significance depending on the measure of presence but being consistent in the sign of the coefficients (Babkin et al., 2017; Delgado, Porter, et al., 2014; Slaper et al., 2018). However, at this level of data aggregation, no significant correlation is found between clusters' presence and GDP per capita, earning per worker, innovation, and unemployment variables, which are commonly linked by researchers and policy makers with the industrial agglomeration. These findings reinforce the idea that the clusters' relations with other phenomena are complex and not so evident at meso and macro levels (Grashof & Fornahl, 2021).

Mention apart deserves the correlation between the clusters' presence and the ICT/ Industry 4.0 Indexes: the sign of the correlation is positive in all the cases and statistically significant for absolute measures of presence. These results support previous findings made at micro-level that suggest that industrial clusters improve the rates of ICT and Industry 4.0 adoption.

Moreover, the research provides to researchers and policy makers with insightful data about the overall level of technological adoption in Spanish regions. This approach overcomes limitations of previous research made in Spain and Europe about Industry 4.0 and industrial clusters, since they rely on case studies, specific regions, or specific technologies (Götz & Jankowska, 2017; Grashof et al., 2021; Hervas-Oliver et al., 2019).

The correlation analysis makes it possible to assess the correlation of individual CCD with the elected variables of economic performance. In this matter, two CCD (the 04 and 05) outperform the correlations showed by the other CCD, even showing statistically significant correlations with variables like GDP per capita and earning per worker. Noteworthy, those two CCD involve engineering and manufacturing related to biochemicals, electronics, machinery, and computing, suggesting that positive externalities could find stronger linkages with those industries, as Tavares et al. (2021) suggest.

The findings provide to practitioners and researchers interested in industrial clusters with useful information to focus their efforts on identifying native competitive networks naturally present over their territory, aiming to develop their industrial clusters in a more effective way. Furthermore, for the Spanish case, policy makers could depart from this paper to assess not only their efforts into developing particular clusters over their regions, but also to put the spotlight on overlooked cross-industry linkages and to develop and improve their territorial presence, aiming to boost their returns and reach new clients and suppliers.

Although economic development and technology adoption are complex phenomena to assess, the results of this research not only provide to researchers, government, and industry leaders a solid basis for industrial policy and competitive strategy, but also a solid methodology to explore the existence of industrial clusters in different contexts. Additionally, the final insights invite researchers to explore the impact of industrial clusters using novel approaches, like the Structural Equation Modeling, capable to identify complex relations among multiple variables that could operate as mediators between the industrial cluster presence and the economic development.

## 6. Conclusions

This research applies, for the first time, a full quantitative methodology of cluster mapping for the Spanish context, adapted from state-of-the-art literature, based on statistical modeling and broadly applicable, with a multi-regional/multi-industry scope. The results find the presence over territory of different industrial clusters based in native cross-industry linkages naturally present over territory, departing from the industrial classification CNAE-2009 2-digits level, and the use of autonomous communities as spatial units to analyze data (NUTS-2), excluding Ceuta and Melilla. Additionally, the study explores the correlations between clusters' presence and a group of relevant variables for the economic development understanding.

The findings contribute to literature from four different perspectives.

First, from a methodological perspective the study demonstrates that even when the foundations of the methodology applied remain the same, there are procedures, criteria, and indicators that researchers must modify or complement with the purpose of improving the results of its application in particular economies.

Second, the conceptual perspective makes a call to researchers and policy makers to question the *representativeness assumption* made over the American cross-industry linkages, and to promote the local CCD creation for individual countries or even for Europe, departing from the quantitative assessment of local cross-industry linkages. The use of homologated-and-foreign CCD for the European case could underestimate relevant linkages or overestimate irrelevant ones, misleading conclusions about clusters' presence, performance, and externalities.

Third, the externalities perspective shows that the clusters' presence measured with absolute employment data correlates better with variables related to education, technology adoption and competitiveness, in contrast to the clusters' presence measured with relative employment and establishments data. Besides, the clusters' presence does not have a statistically significant correlation with expected variables like GDP per capita, earning per worker and innovation, but it maintains the expected correlation sign. These final insights invite researchers to explore the impact of industrial clusters using different approaches to find more complex relations among variables.

Fourth, from the practical perspective this paper offers, right out-of-the-box, useful information to take the regional and industrial assessment further. Researchers, policy makers, and practitioners can find the list of industries classified as traded, the groups of industries that shape each CDD, the clusters' location, and even two indexes of technological adoption for all autonomous communities (ICT and Industry 4.0 indexes). The index construction presented in this paper is the first one to group into a single indicator the technology adoption of different regions using harmonized data for all of them, being the first exercise of its kind for Spanish regions.

Nonetheless, the study is limited by the aggregation level of the data, not to mention that complete data for some industries is unavailable or hidden due to statistical confidentiality. Thus, although there are challenges related to more complete and disaggregate data availability, further analysis is recommended at NUTS-3 and CNAE-2009 3-digits to generate more detailed CCD and provide useful information at even more local level. Additionally, this could make it possible deep exploration of relations among variables, using inferential statistics as Ordinary Least Squares regression and Structural Equation Modeling. Furthermore, this research's methodology could be improved including indicators related to technological similarity, community linkages, and natural advantages, which would be helpful to find novel cross-industry linkages departing from other approaches like the industrial district mapping.

Finally, this research shows a contemporaneous outlook to industrial structure in Spain and expects to be useful not only as a benchmark for future research, but also for policy makers and industry leaders currently working on industrial policy and competitive strategy.

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Articles

# Okun's Law: The effects of the COVID-19 pandemic and the temporary layoffs procedures (ERTEs) on Spanish regions

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## Abstract:

Official statistics indicated a break in Okun's law in all the Spanish regions due to the COVID-19 pandemic; however, herein, evidence of the validity of the law is shown. The temporary layoff procedures (ERTEs) allowed many workers to maintain their jobs. From the productive point of view, the law remained in effect in the regions, showing a strong relationship between idle labour resources and economic activity, and from the social point of view, the apparent breakdown of the law can be interpreted as the implementation of a policy that mitigated the dramatic impact of the economic crisis.

**Keywords:** Okun's law; ERTE; expanded unemployment rate.
**JEL Classification:** E23; E24; J64.

## Ley de Okun: Los efectos de la pandemia de COVID-19 y los procedimientos de despido temporal (ERTE) en las regiones españolas

## Resumen:

Las estadísticas oficiales indicaban una ruptura de la ley de Okun en todas las CCAA por la pandemia del COVID-19, sin embargo, aquí se muestra evidencia sobre la vigencia de la ley. Los ERTE permitieron el mantenimiento del vínculo laboral de muchos trabajadores. Desde el punto de vista productivo se observa que la ley continuó vigente mostrando una fuerte relación entre los recursos laborales ociosos y la actividad económica, y, desde el punto de vista social, la aparente ruptura de la ley puede interpretarse como la implementación de una política que mitigó el dramático impacto de la crisis económica.

**Palabras clave:** Ley de Okun; ERTE; tasa de desempleo ampliado.
**Clasificación JEL:** E23; E24; J64.

## 1. Introduction

Did Okun's law fail in Spain after the COVID-19 pandemic? Okun's relationship that was known prior to the health crisis unleashed by COVID-19 infections indicated for Spain that, for each percentage point (pp) of growth in economic activity, unemployment dropped by approximately one percentage point.

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If this relationship had been complied with, the unemployment rate should have increased to 35% in the second quarter of 2020 since economic activity fell by 21.5%. However, the unemployment rate barely increased 1.3 pp and stood at 15.3%.

Unemployment recorded by official statistics is measured from the criteria of the International Labor Organization (ILO) and indicates, from the point of view of people, the total lack of employment and, from the point of view of production, the existence of idle resources. However, as Dolado et al. (2021) note, during the COVID-19 pandemic, the unemployment rate has not been a good indicator of the underutilization of labour. Following the methodology of the United States Bureau of Labor Statistics, these authors introduce different alternative indicators to that of the conventional unemployment rate. Added to this measurement, are people who stopped looking for work but were available to start a job, and workers covered by the temporary layoff procedures (called ERTE in Spanish for "*Expediente de Regulación Temporal de Empleo*") for suspension of contract or reduced working day. This unemployment rate, in a broader sense, reached, according to the authors, 40.6% of the economically active population in the second quarter of 2020.

From the perspective of the production function, where there is a positive relationship between the demand for productive factors and production, the variation in economic activity also implies variations in the requirements of productive factors, specifically the labour factor. With the dramatic fall in the level of activity due to the restrictions placed on mobility imposed during the COVID-19 pandemic, some workers lost their jobs, while others, from the implementation of various measures of job retention policies, suffered a partial reduction in their working hours or a complete and temporary suspension of the employment contract. In this way, many resources became idle when economic activity fell, in accordance with this positive relationship between economic activity and the demand of the labour factor, thus validating Okun's law, which is based on production logic, although this was not reflected in the estimated Okun's coefficient based on unemployment statistics due to the implementation of these policies.

It is logical to think that Okun's underlying relationship did not change from the COVID-19 pandemic forward and that, beyond the cyclical variations of the labour supply (Martín-Román, 2022), it is the way in which idle labour resources are measured, which explains why the variable "unemployment rate" would have reflected the evolution of only a part of the resources that were idle over the pandemic. In turn, to the extent that this would respond to the implementation of policy measures protecting jobs and reducing the negative socioeconomic impact on people implied by the COVID-19 pandemic crisis, the difference between the expected impact on unemployment based on the previous estimates of Okun's relationship and what actually happened can be interpreted in part as the positive impact of the economic policy implemented (Leandro, 2020; Barišić & Kovač 2022).

On the other hand, given that the crisis caused by the COVID-19 pandemic had differentiated impacts at the sectoral and territorial levels, the impact of mobility restriction measures and the palliative employment policy measures implemented also had varied intensities in the different regions of Spain. According to Romero et al. (2021), the differential economic impacts in the sector are noticeable, since the most affected sectors have been those involving greater social contact (retail trade, hospitality, restaurants, transport, leisure and cultural activities). As a consequence of the differentiated impact in the sector, effects of different magnitudes were also generated at the territorial level, since the provincial economies most affected by the COVID-19 crisis were those with the highest level of specialization in some of those sectoral activities that were most hit by the crisis. It is therefore not surprising that the regions most affected have been those of the two archipelagos (Balearic and Canary Islands) and some provinces on the Mediterranean.

Therefore, in this research, we try, first, to analyse the validity of Okun's law at the level of the Spanish regions (NUTS II) and to identify the change that occurred since the COVID-19 pandemic. Next, with a broader measure than that of the official statistics that includes the people covered by the ERTEs, which also represent idle resources from the productive point of view, we estimated the Okun's relationship for each region of Spain, whose results describe the continuity of this relationship throughout the Spanish territory. Finally, as a way to evaluate the positive impact of the implemented employment protection policy, we projected the unemployment rate of each region for the four quarters of the first year of the COVID-19 pandemic from the pre-pandemic data and compared these results with the real evolution of unemployment and with "extended" unemployment. The results vary according to region, but in all cases, it is concluded that if this policy had not been mediated, the unemployment rate would have been sitting, depending on the region, between 8pp and 31pp above the level recorded by the statistics of the National Institute of Statistics (INE) in the quarter with the greatest negative impact on economic activity due to COVID-19 (2020.Q2).

The article is structured as follows. Section 2 presents a brief description of the evolution of the COVID-19 pandemic and the implementation of ERTEs in Spain. The evidence shown in the literature on the application of workforce reduction strategies and their impacts is discussed in section 3. Then, Okun's law and the empirical evidence for Spain are formally presented in section 4. Next, section 5 describes the methodology and data used in this research; in section 6, the results are presented; and finally, the conclusions are presented.

## 2. Background

### 2.1. COVID-19 and the ERTE

The first case of COVID-19 in Spain was diagnosed in January 2020. After it, and due to its rapid expansion, the government decreed a state of alarm in March, suspending nonessential activity and establishing the confinement of the majority of the population. Limiting mobility, as well as the hibernation of the economy, allowed reducing the number of infections, following successive extensions of the state of alarm, in a process of asymmetric de-escalation in April 2020. The de-escalation gave rise to a certain relaxation of the containment measures during the summer months.

Unfortunately, after the summer, infections increased again, causing the issue of a new state of alarm, albeit of a different nature. In this new stage, health containment measures were decentralized to the regions, establishing a great heterogeneity of action scenarios. Limiting mobility, setting curfews or local confinements were some of the measures applied by the governments of the Spanish regions.

In December 2020, the vaccination process of the population by age group began, and with it, both infections and deaths were gradually reduced, which allowed the progressive lifting of the restrictive measures implemented.

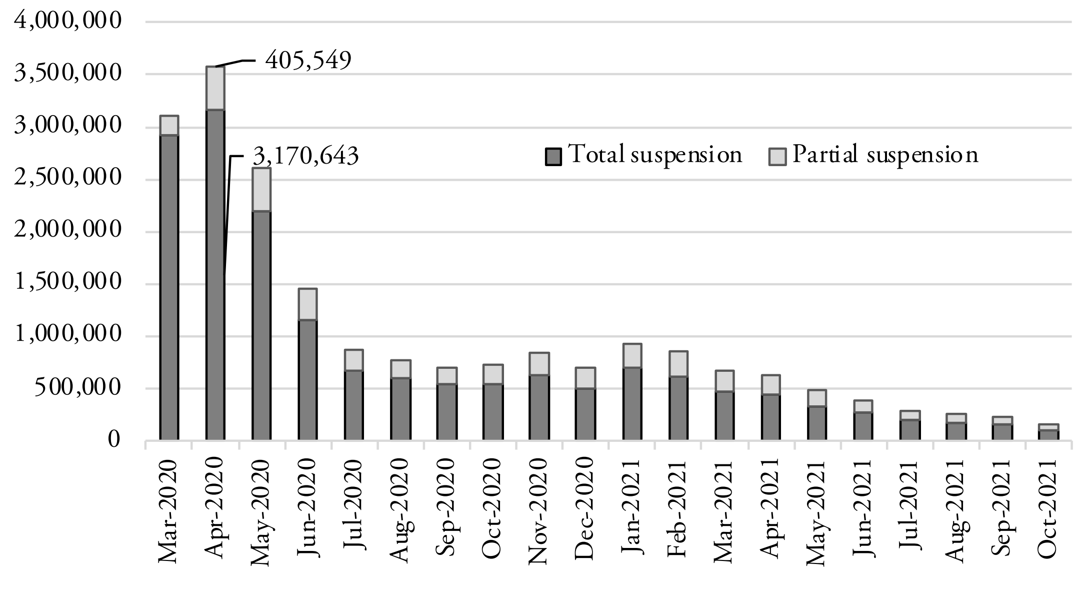
In labour matters, as the health crisis developed, measures were implemented to defend jobs and support the unemployed. **Royal Decree-Law 8/2020** (03/17/2020) allowed the application and development of ERTE. The ERTEs were established as a procedure that allowed companies the total suspension of contracts or the reduction of the working day on a temporary basis. Therefore, the workers covered by ERTEs constitute a group of people who would surely have joined the ranks of the unemployed had this measure not existed. The ERTEs born in the pandemic are regulated in Article 47 of the Workers' Statute and update or adapt, due to the exceptional circumstances imposed by the pandemic, the former layoff procedures (ERE) for economic, technical organizational or production (ETOP) reasons. The workers under the ERTEs maintain their status as employees both at the level of Social Security and in the statistics of the Labour Force Survey (LFS) of the INE, so they do not become part of the unemployed count.

After the initial establishment of the ERTEs in March 2020, successive regulations in the form of the Royal Decree (RD) have been extending their use and extension more or less automatically. Certainly, complex legislation has been established where we highlight the main measures developed.

- **Royal Decree-Law 15/2020** (04/21/2020), on urgent complementary measures to support the economy and employment, modified the regulation of ERTEs due to force majeure provided for in Royal Decree-Law 8/2020, of extraordinary urgent measures to address the economic and social impact of COVID-19, establishing that force majeure may be partial.
- **Royal Decree-Law 30/2020** (09/29/2020) made possible the automatic extension of the ERTE in force until January 31, 2021.

- **Royal Decree** (01/26/2021), again extended the ERTEs based on a force majeure related to COVID-19, regulated in article 22 of Royal Decree-Law 8/2020 until May 31, 2021.
- **Royal Decree-Law 11/2021** (05/27/2021), on urgent measures for the defence of employment, economic reactivation and protection of self-employed workers, included a series of measures that affect unemployment benefits, as well as the automatic extension until September 30, 2021.
- **Royal Decree-Law 18/2021** (09/28/2021), of urgent measures for the protection of employment, economic recovery and job improvement, established a new extension until February 28, 2022, of the ERTEs in accordance with various articulations.
- In short, through successive extensions, the ERTEs have been maintained over time, allowing the country to cope with the pandemic, although it is also true that it has been carried out under the public budget and that its management has presented certain inefficiencies. As shown in Figure 1, the ERTEs were intensively applied when first established, reaching more than 3 and a half million workers sheltered under this modality, mostly with total suspension; subsequently, it was gradually reduced until reaching the official figure of 292,722 workers in ERTEs in July 2021.

FIGURE 1.
**Affiliates in the ERTE linked to the COVID-19 according to type of suspension**




**Source:** Ministerio de Inclusión, Seguridad Social y Migraciones

## 2.2. Evidence on the application of workforce reduction strategies

The workforce reduction strategies have been analysed by academic literature from different perspectives. Since its inception, the analysis has focused on the study of short-time work (STW) tools, attempting to demonstrate whether these systems are effective tools for maintaining employment in times of economic crisis, compared to traditional benefit systems.

Pioneering studies from the 1990s validated the use of STW as a form of employment preservation. Publications such as Abraham & Houseman (1994) and Van Audenrode (1994) show their effectiveness in retaining jobs. Similarly, during the Great Recession of 2008, Giupponi & Landais (2020) and Pavlopoulos & Chkalova (2022) also established that STW was a useful tool for job preservation and overcoming the crisis. Arranz et al. (2021) demostrated that STW effectively preserved jobs in Spain during the 2008 crisis. However, as the use of STW became more widespread, some criticisms also emerged in the academic literature. The results obtained were heavily dependent on the environment and the type of STW implementation.

The heterogeneity of results based on the environment was confirmed through cross-country comparative studies. Lea (2020) analyzed the international diffusion of these systems, highlighting a high heterogeneity of implementation. In a study of 19 OECD countries during the 2008 crisis, Hijzen & Venn (2011) found a positive impact only in the case of Germany and Japan.

Nevertheless, each country has carried out these systems differently, through subsidies to companies, social security contribution suspensions, tax exemptions, etc., making international comparisons complex. Fitzroy & Hart (1985) argue that STWs were efficient in the US not only due to the institutional context but also because of their different application through payroll tax systems. Burdett & Wright (1989) compared systems based on unemployment insurance perception against reduced working hours using a theoretical model and statistical evidence, showing that while the latter preserved employment, it could result in inefficient hours per worker. Osuna & García-Pérez (2015) evaluated STWs based on the 2012 labour reform using a matching model demonstrating that STWs do not necessarily reduce unemployment or lost jobs, so that the effectiveness of the system depends on the degree of subsidy implemented. In a more recent work, Osuna & García-Pérez (2021) analysed schemes for reducing working hours during COVID-19, assessing the need to implement these schemes in light of the increase in the fiscal deficit. The authors state that STWs do not prevent the increase in unemployment and the job destruction, as their adverse effects depend on the degree of subsidies implemented and the design of the regulations themselves.

Overall, a significant portion of the academic literature focuses on analysing different systems implemented by countries to defend employment, concluding that these systems are palliative and generally temporary. Burdett & Wright (1989) advocate the use of STW systems only temporarily. In the case of Spain, Arranz et al. (2019) analyse the propensity to lay off workers during the crisis of the early 1990s compared to the crisis of the late 2000s, showing that the job preservation policy through STW should focus on the short term and always take into account the composition of the workforce.

Apart from confirming the positive aspects of STWs while acknowledging their limitations, Hijzen & Venn (2011) indicate that the positive impacts are limited, as the segmentation of the labour market increases between workers with full-time jobs and workers with temporary and part-time jobs. In a later study, Hijzen & Martin (2013) stated that the positive impact depended on the timing of program implementation and that their use during the recovery period could have slowed job creation. The study by Boeri & Bruecker (2011) suggests that these systems come with significant "dead weight" costs, meaning that the number of jobs "saved" is estimated to be fewer than the number of jobs covered by the programs. Cahuc & Carcillo (2011) also point out that these systems can lead to an inefficient reduction in hours worked, and later Cahuc et al. (2021) argue that they significantly increase the costs of public policies.

With the COVID-19 crisis, the STW systems have been reintroduced as a measure for the preservation of employment, with a greater intensity, given that, in this period, the suspension of employment has been for total working time. Studies have largely focused on the analysis of the furloughed workers schemes (FWS) or job retention (JR) schemes. However, the academic discussion has again focused on the validity of these instruments as a defence of employment against traditional systems. Juranek et al. (2020) analyses layoffs during the COVID-19 crisis in Norway using administrative data, demonstrating that the FWS limited the impact of the pandemic. The work of Stuart et al. (2021) shows that the FWS system has helped retain jobs in the United Kingdom and should be implemented as part of companies' human resources policies for workforce retention. Castle et al. (2021), using forecasting techniques, demonstrate that furlough policies have stabilized unemployment in the United Kingdom. Pope et al. (2020) show, through statistical analysis, that job retention schemes have mitigated the negative effects of the pandemic on the labour market in the case of the United Kingdom, although the extension of these schemes varied across sectors. However, the effectiveness of such measures was mainly observed in the short term. Research of Izquierdo et al. (2021) shows how the FWS was the most used tool for the Spanish labour market adjustment in the face of the global pandemic, particularly during the second quarter of 2020 due to economic activity restrictions.

Nonetheless, the comparison should be made with caution given that until recently, these types of schemes have not been analysed in depth, and we still do not have sufficient historical perspective for their assessment. Additionally, the environment and the different modes of implementation are once again emphasized as key factors for the success of such tools.

From a global perspective, the analysed macroeconomic effects of both measures (STW and FWS) are generally positive in relation to job preservation and preventing layoffs, but they also tend to have some adverse effects in relation to labour costs, reduced wages, inefficiencies and dead weights. Moreover, these measures accentuate the segmentation between employed and unemployed workers in the labour market. However, the legislative characteristics of each measure prevent a detailed comparison at the aggregate level so that the legislative framework is decisive in the success of the measures. Finally, it is worth noting that the majority of the authors advocate for these measures to be temporary or established for a limited duration, specifically during periods of economic recession.

This research contributes to the literature on the effects of total suspension FWS systems in the Spanish context, where the existing literature is still emerging.

## 2.3. Okun's law

Okun's law establishes the inverse relationship between unemployment and economic activity (Okun, 1962). This relationship has been estimated in different ways, with the modelling in differences (1) and in gaps (2) being the most used (Porras-Arena & Martín-Román, 2023).

$$u_t - u_{t-1} = \beta_0 + \beta_1 g_{yt} \quad (1)$$

$$(u_t - u_t^*) = \gamma_0 + \gamma_1 (y_t - y_t^*) \quad (2)$$

where $u_t$ is the unemployment rate, $g_{yt}$ the growth rates of the economy, $u_t^*$ the natural unemployment rate, $y_t$ the logarithm of the output and $y_t^*$ the logarithm of the potential output. $\beta_1$ in (1) and $\gamma_1$ in (2) correspond to the so-called Okun's coefficient, which takes a negative value. In the first case, this coefficient indicates how much the unemployment rate decreases when economic activity grows by 1%, and in the second case, how much the unemployment rate moves away from its potential or natural level when economic activity moves away by 1% from its potential level.

Table 1 shows the results for Spain of the studies that estimate Okun's law for several developed countries. The values vary depending on the period or the methodology used and are between -0.63 and -0.94. In all cases, the estimated coefficients indicate that Spain's unemployment rate is most sensitive to changes in economic activity. On the other hand, Buendía & Sánchez (2017) estimated, with panel data from Spanish provinces, at 2.5% to the minimum growth rate that the Spanish economy should register to achieve reductions in unemployment (2001-2011), which is equivalent to an Okun's coefficient at a lower level in absolute value than those in the range of values indicated above. However, the authors do not indicate what might account for these differences.

In this way, the forecasts on the evolution of unemployment, in the context of the collapse of economic activity due to the health measures imposed by the COVID-19 infection, predicted a dramatic increase in the number of people who would lose their jobs and would swell the ranks of the unemployed.

On the other hand, there are studies that indicate that the Okun's relationship varies at the regional level in Spain (Villaverde & Maza, 2009; Bande & Martín-Román, 2018; Porras-Arena & Martín-Román, 2019), due, among other things, to differential characteristics of their labour markets. This implied at the beginning of 2020 regional differentiated forecasts about what could be the increase in unemployment in the context of a probable fall in economic activity due to COVID-19. In addition, as already indicated, the Government of Spain determined at some point the decentralisation of health containment measures to the regions, establishing a great heterogeneity of action scenarios. That is why the analysis of the effects of the COVID-19 pandemic and of the ERTEs on Okun's law is carried out in this research at the level of the Spanish regions (NUTS II).

**Table 1.**
**Estimates of Okun's law for Spain**

| Author | Period | Okun coefficient |
|---|---|---|
| Perman & Tavera (2005) | 1970-2002 | -0.79 |
| Perman & Tavera (2007) | 1970-2002 | -0.71 |
| Ball et al. (2017) | 1980-2013 | -0.94 |
| | | -0.82 |
| | | -0.8 |
| | | -0.74 |
| Jalles (2019) | 1978-2015 | -0.9 |
| | | -0.89 |
| | | -0.81 |
| Gil-Alana et al. (2020) | 2000-2015 | -0.69 |
| | | -0.66 |
| | | -0.63 |
| Villanueva and Cárdenas (2021) | 1998-2018 | -0.73 |

Several studies report the differences between regions of Spain with respect to the reaction of unemployment to changes in economic activity (or the inverse relationship). Some authors estimated the relationship for one single region and compared it with that of the country as a whole (Pérez et al., 2003; Usabiaga & Hernández-Salmerón, 2021). Other authors estimated the relationship for each region (Villaverde & Maza, 2007, 2009; Bande & Martín-Román, 2018, Porras-Arena & Martín-Román, 2019) and found significant differences in the estimated coefficients. Melguizo (2017), on the other hand, carries out the study of the relationship at the provincial level in Spain, suggesting with the results obtained that it is also appropriate to consider a greater territorial division to analyse Okun's law (50 provinces instead of 17 regions). The results obtained by Clar-López et al. (2014) show additional elements on the relative importance of studying Okun's law at the regional level in Spain, since they found that applying this relationship improves the predictive capacity of econometric models in such a way that the unemployment rate in most regions is predictable.

On the other hand, Usabiaga & Hernández-Salmerón (2021) found that the Okun's coefficients were -0.8 and -0.7 for Spain and Andalusia, respectively, with data up to 2019. However, when re-estimating the relationship incorporating the data since 2020, there is a significant change in the regression results, obtaining relationship coefficients lower in absolute value and lower coefficients of determination ($R^2$) as well. The new estimates are approximately -0.4 for both cases. According to the authors, the strong shock caused by the pandemic and the widespread use of ERTEs would be the factors that would explain these results.

Barišić & Kovač (2022), based on estimations of Okun's law for a total of 26 European countries, including Spain, projected the expected values of the variation in the unemployment rate for the first and second quarters of 2020 compared with real variations. For several countries, the difference between the projected value and the true value shows a positive sign, with Spain standing out among them. These differences are interpreted as the successful application of fiscal policy measures to mitigate the negative impacts of the COVID-19 crisis.

Likewise, with the objective of evaluating the effectiveness of the fiscal effort in times of pandemic by COVID-19, Leandro (2020) estimated Okun's law for several countries in Europe which implemented measures much like those of Spain's ERTEs. Based on these models, the respective unemployment rates for the first and second quarters were projected and compared with the current ones, showing that in Spain, the negative effect of the crisis on employment is significantly reduced, mainly in the second quarter of 2020.

## 3. Methodology and data

When working with quarterly data, it is common to find dynamic estimates of Okun's law, which include delays of the dependent and independent variables. For the difference model, it would be:

$$\Delta u_t = \alpha + \sum_{i=1}^{p} \delta_i \Delta u_{t-i} + \sum_{i=0}^{q} \beta_i g_{yt-i} \tag{3}$$

where $u_t$ is the unemployment rate and $g_{yt}$ the growth rates of the economy.

In this case, it is not only the coefficient of the contemporary relationship that matters but also the total effect that operates through the lags of the variables, which is the one that is comparable with the effect that is calculated from the variables with annual periodicity. The total effect is calculated as follows:

$$Total\ effect = \frac{\sum_{i=0}^{q} \beta_i}{(1-\sum_{i=1}^{p} \delta_i)} \tag{4}$$

The estimation process was carried out in three stages. The first consisted of estimating the dynamic Okun relationship (3), using the INE unemployment rate (UR) as dependent variable. We estimated Model 1, which includes data from 2005.Q1 to 2019.Q4 and compared the results with those of Model 2, which includes data up to 2020.Q4. This is the procedure used by Usabiaga & Hernández-Salmerón (2021) to study the case of Spain and Andalusia, which allows us to observe the changes that were processed in Okun's relationship when the crisis caused by the COVID-19 pandemic was unleashed. But, as Dolado et al. (2021) note, during the COVID-19 pandemic, the unemployment rate has not been a good indicator of the underutilization of labour and therefore, the Okun's relationship estimated with INE's UR as dependent variable does not reflect the true relationship between unemployment and output.

Thus, the second stage consisted, in the first place, in constructing for each region a new variable: "expanded unemployment rate" (URE), reflecting the existence of idle labor resources. That is, a variable that included the unemployed and the workers covered by the former EREs and currently by the ERTEs. By using the microdata from the LFS of the INE, we identified those individuals who were not classified as unemployed by the INE since they were in furlough schemes. Then we added them to the unemployed persons computed by the INE to obtain the figures relative to URE variable within each region:[1] The objective of having this new variable was to have an approximate measure of the level that unemployment might have reached in the absence of the palliative policies that were applied due to the COVID-19 pandemic, such as the ERTE program.

Using the new variable URE, we proceeded to estimate first the dynamic Okun relationship (3) for each region, using URE variable as dependent variable for the period 2005.Q1-2019.Q4 (Model 3). Considering that prior to the COVID-19 pandemic the application of temporary programs such as the ERE had very limited utilization, we expect the estimation results of Model 1 to be similar to those of Model 3. Then, we proceeded to estimate the dynamic Okun relationship (3), using URE variable as dependent variable but for the full period (2005.Q1-2020.Q4) (Model 4). Since the URE variable collects information on idle labor resources, whether or not they are counted as unemployed by the INE, we expect the estimated relationship for the full period between URE and output to be strong, as was the relationship between UR and output in the pre-pandemic period of COVID-19 for Spain. If this is confirmed, we will be able to conclude that Okun's relationship remained in place during the COVID-19 pandemic with no structural changes.

In the third stage, like Leandro (2020), we project the unemployment rate (UR) for each region for the four quarters of 2020, based on Okun's law estimated for the pre-COVID-19 period (*Model 1*) and considering the evolution of the economic activity in those four quarters. Then, we compared those projections with the actual values of the INE unemployment rates. This allows us to identify, on the one hand, the effect of the application of the ERTEs on unemployment, i.e., what could have been expected to happen to unemployment in the absence of this policy. On the other hand, in this article we also

[1] Data are available from authors upon request.

compare the results of these projections with those of the URE variable. The closer these two variables are, two things can be concluded: 1) the URE variable would be the unemployment rate if the application of the ERTE had not been mediated, that is, unemployment would have grown significantly; 2) the nearly fit between the UR projections and URE implies that Okun's relationship continued in force even in the pandemic period.

Regarding the data used, the microdata of the LFS of the INE (2005-2020) were processed to construct the UR and URE series for each region on a quarterly basis. The URE implies a broader notion of unemployment than that established using the ILO criteria, since the latter records the total lack of employment (with availability to work and actively seeking employment).

Regarding the variable related to output, the quarterly GDP series of the regions prepared by the Independent Authority for Fiscal Responsibility (AIREF) were used. According to the methodology, the construction of these variables combines three types of statistical information for regional analysis: the monthly data of economic indicators broken down at the territorial level, the annual data compiled by the Spanish Regional Accounts and the estimates for the national set published by the Quarterly National Accounts.

## 4. Results

### 4.1. Regional Okun's law in Spain

As a first step prior to modelling, unit root tests were performed on the variables. As the model being estimated (equation (3)) contains the variables in first differences, the unit root tests were performed on the variables in first differences. In all cases the null hypothesis of the existence of a unit root was rejected (Table A.1 of the Appendix), so it is possible to apply the Ordinary Least Squares method to estimate the parameters of interest.

As mentioned in the methodological section, the first estimation stage consisted of estimating Okun's law for the Spanish regions using the official unemployment rate (UR) as dependent variable. The first four columns of Table 2 show the results of *Model 1* and *2*, which differ in that *Model 1* goes through the last quarter of 2019, and *Model 2* also includes the four quarters of 2020. The coefficients reflect the total effect (equation (4)) of the variations of GDP on unemployment, that is, the one that results once the lagged effects of all the variables (dependent and independent) have operated. The table shows the results of the specifications of the models whose residuals passed the Normality, Heteroscedasticity and Autocorrelation tests (Table A.2 of the Appendix).

As seen in the first column of this table, the Okun's coefficients were relatively high in absolute value in the different regions before the crisis unleashed by COVID-19 (*Model 1*), although there was great dispersion, oscillating between a coefficient of -0.34 in the Balearic Islands to -1.25 in the Canary Islands. As a point of comparison, Ball et al. (2019) estimated the mean value of the Okun's coefficient in advanced economies at -0.4. On the other hand, in some regions, the adjustment coefficient of the model ($R^2$) is relatively low, which indicates that the variations in economic activity would not explain all the variability of the unemployment rate.

We next analyse the existence of any regional pattern with respect to the response of unemployment to output changes in the pre-pandemic period of COVID-19. To do so, we estimate Moran's I statistic and Geary's C statistic that inquire about the possible spatial autocorrelation of the data, using three different spatial weight matrices: the inverse of the standardised distance, the five nearest neighbours and the three nearest neighbours. We do not include the Canary Islands in the analysis because of their spatial remoteness. The results of the tests are presented in Table 3, and as can be seen, in all cases the null hypothesis indicating the absence of spatial autocorrelation is not rejected. This was an expected result, given that the study by Villaverde & Maza (2009), using also Moran's I with the inverse of the standardised distance matrix over Okun's law in Spanish regions, does not find a spatial pattern in the results either. Variables such as the rate of productivity growth (Villaverde & Maza, 2009) or the importance of self-employment (Porras-Arena & Martín-Román, 2019) are pointed out as factors influencing the different levels of reaction of output to unemployment in the first case and of unemployment to output in the second case.

**TABLE 2.**
**Regional Okun's coefficients**

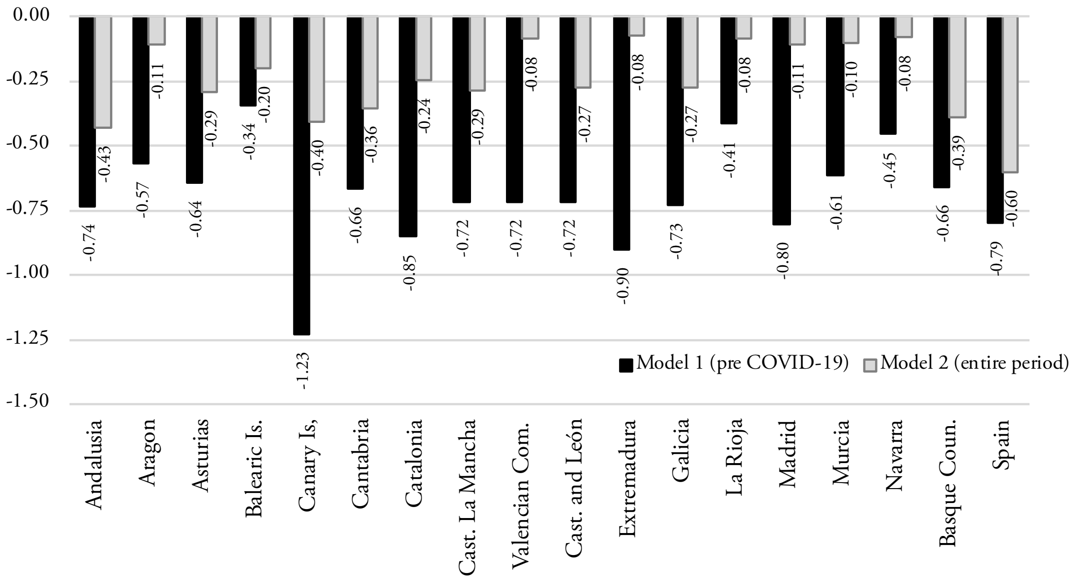
| Region | Dependent variable: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unemployment rate (UR) | | | | Expanded Unemployment Rate (URE) | | | |
| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
| | *Okun coef.* | $R^2$ | *Okun coef.* | $R^2$ | *Okun coef.* | $R^2$ | *Okun coef.* | $R^2$ |
| Andalusia | -0.74 | 0.82 | -0.43 | 0.75 | -0.72 | 0.82 | -0.99 | 0.98 |
| Aragon | -0.57 | 0.46 | -0.11 | 0.38 | -0.59 | 0.47 | -1.06 | 0.95 |
| Asturias | -0.64 | 0.47 | -0.29 | 0.41 | -0.71 | 0.46 | -1.14 | 0.93 |
| Balearic Islands | -0.34 | 0.90 | -0.20 | 0.91 | -0.58 | 0.57 | -0.74 | 0.98 |
| Canary Islands | -1.25 | 0.52 | -0.40 | 0.56 | -1.25 | 0.52 | -1.42 | 0.95 |
| Cantabria | -0.66 | 0.16 | -0.36 | 0.19 | -0.72 | 0.18 | -1.07 | 0.93 |
| Catalonia | -0.85 | 0.71 | -0.24 | 0.68 | -0.86 | 0.64 | -1.06 | 0.98 |
| Castilla La Mancha | -0.72 | 0.58 | -0.29 | 0.55 | -0.70 | 0.36 | -0.81 | 0.86 |
| Valencian Community | -0.72 | 0.86 | -0.08 | 0.76 | -0.85 | 0.64 | -0.92 | 0.97 |
| Castile and León | -0.72 | 0.53 | -0.27 | 0.46 | -0.75 | 0.60 | -0.99 | 0.98 |
| Extremadura | -0.90 | 0.33 | -0.08 | 0.36 | -0.93 | 0.38 | -0.97 | 0.84 |
| Galicia | -0.73 | 0.58 | -0.27 | 0.51 | -0.74 | 0.57 | -0.97 | 0.98 |
| La Rioja | -0.41 | 0.20 | -0.08 | 0.17 | -0.49 | 0.27 | -0.89 | 0.86 |
| Madrid | -0.80 | 0.44 | -0.11 | 0.34 | -0.82 | 0.49 | -1.07 | 0.97 |
| Murcia | -0.61 | 0.23 | -0.10 | 0.33 | -0.62 | 0.31 | -0.69 | 0.86 |
| Navarra | -0.45 | 0.48 | -0.08 | 0.34 | -0.58 | 0.57 | -0.96 | 0.91 |
| Basque Country | -0.66 | 0.65 | -0.39 | 0.54 | -0.81 | 0.50 | -1.03 | 0.97 |
| Spain | -0.79 | 0.94 | -0.60 | 0.90 | -0.79 | 0.94 | -0.91 | 1.00 |

**Notes:** UR is the unemployment rate of the LFS. URE is the expanded unemployment rate (unemployed + people covered by the ERTE). The period in Model 1 and 3 is 2005.Q1 – 2019.Q4 and in Model 2 and 4 is 2005.Q1-2020.Q4. The coefficients for each region and each model correspond to the total effect of GDP on the dependent variable (UR or URE), equation (4).

**TABLE 3.**
**Spatial autocorrelation test: Moran's I and Geary's C**

| | Moran's I | | Geary's c | |
|---|---|---|---|---|
| Weights matrix | **Statistic** | **p-value** | **Statistic** | **p-value** |
| Inverse Distance | -0.01 | 0.23 | 0.92 | 0.15 |
| 5 nearest neighbors | 0.05 | 0.31 | 0.83 | 0.19 |
| 3 nearest neighbors | 0.03 | 0.56 | 0.85 | 0.40 |

**FIGURE 2.**
**Regional Okun's coefficients with the unemployment rate (UR) as dependent variable**




When data from the four quarters of 2020 were included in the estimates (*Model 2*), it is seen that the Okun's coefficients are significantly lower in absolute value (Table 2 and Figure 2), that is, with only four additional data. Moreover, the relationship for the entire period becomes weaker in all regions. The reduction of the estimated coefficient ranges from 0.27pp to 0.83pp in absolute value, depending on the region (on average 0.47). These four additional observations correspond to the period in which, although economic activity was dramatically reduced in all regions, unemployment did not see the expected increase according to the pre-pandemic Okun's relationship. In addition, to achieve significant coefficients and model adjustments, more lags of the variables had to be included in many cases. With these results, it seems that the relationship between unemployment and economic activity would have undergone a structural change in 2020 for all regions of Spain.

In the second stage, Okun's relationship (*Model 3* and *Model 4* of Table 2) was estimated using the "extended unemployment rate" (URE) as the dependent variable for the same periods than *Model 1* and *2* respectively. As shown in Figure 3, there are no significant differences in the estimates with pre-pandemic data between the use of UR or URE as a dependent variable in the modelling. This was a predictable result, since the large differences between these two variables are concentrated in the pandemic period, with the implementation and extensive use of ERTEs.

Then, when data from the four quarters of 2020 are added to the estimation with URE, it is observed that the relationship becomes even stronger in all regions (Figure 4), and the models offer, in almost all cases, an adjustment coefficient above 0.9. This is because we are adding data that show a period in which economic activity collapsed in each region, and at the same time, the URE was subject to a significant increase, mainly in the second quarter of 2020, due to a slight increase in registered unemployment together with a large increase in "hidden unemployment" linked to the containment exercised by the ERTEs. Therefore, the doubt arises that if the people who took advantage of the ERTEs had been counted as idle resources (unemployed) in the labour market statistics or if they had not mediated these employment containment policies, most of these people would have become strictly unemployed. Therefore, the original Okun's relationship, which takes UR as a dependent variable, not only would not have become weaker but, on the contrary, would have become stronger, showing a solid impact of variations in activity on unemployment.

**Figure 3.**
**Regional Okun's coefficiencts with UR (Model 1) and URE (Model 3)**

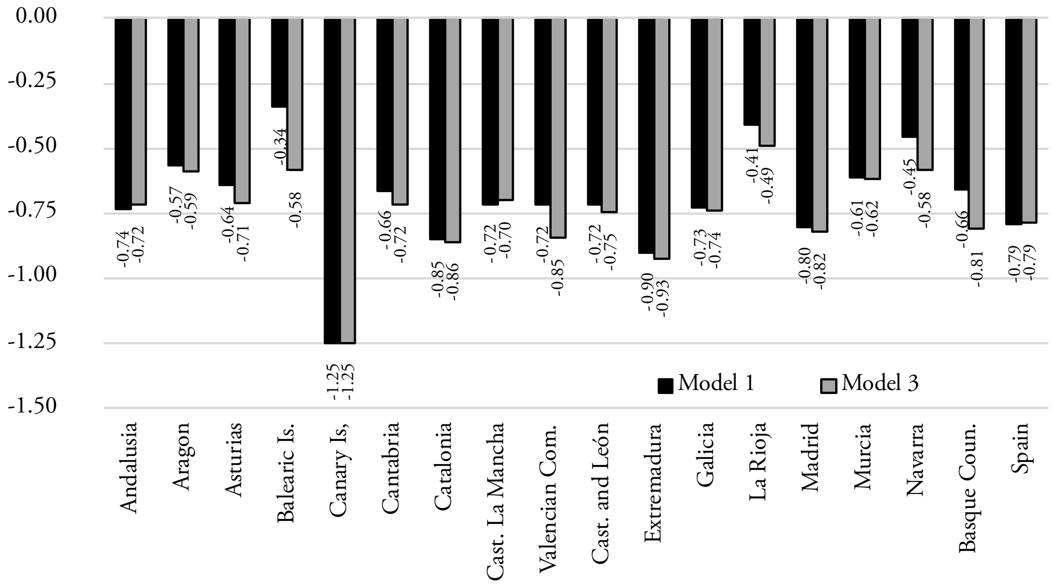
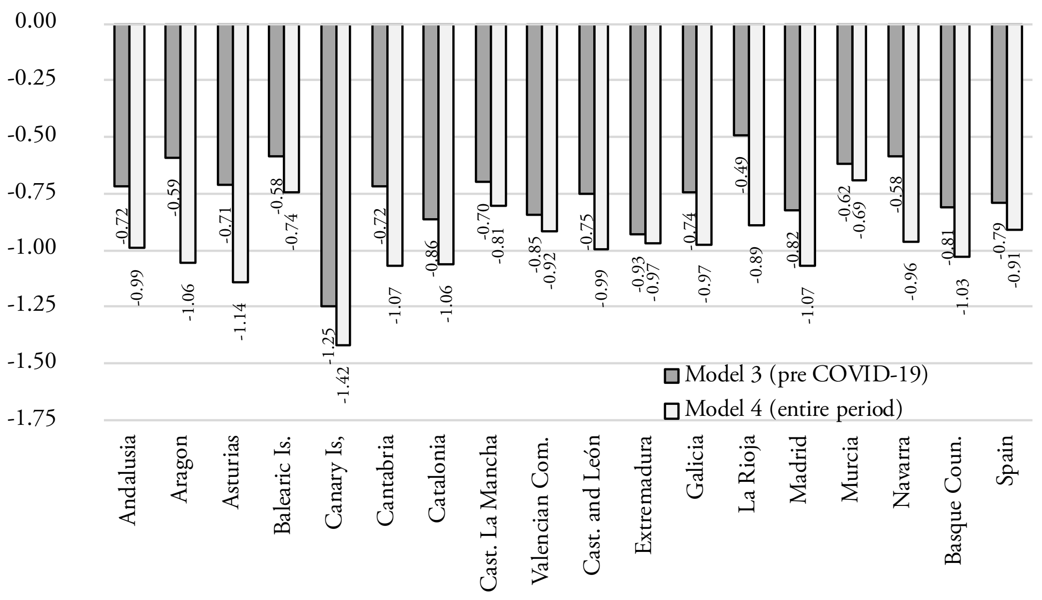



**Figure 4.**
**Regional Okun's coefficients with expanded unemployment rate (URE) as dependent variable**




## 4.2. Projected UR

From the previous analysis it is clear that if the people who had been taken in by the ERTEs had been counted as unemployed, given that they were not actually employed, Okun's law, which relates the unemployment rate and output, would not have suffered significant alterations in the Spanish regions during the economic crisis provoked by the COVID-19 pandemic. As a way of reinforcing this hypothesis, in the third stage of this research, we compare the real unemployment generated during the COVID-19 pandemic, that is, the one that includes the unemployed as counted by the INE plus the "hidden unemployment", that is workers covered by the ERTEs, with the unemployment expected from the dramatic fall in economic activity during the pandemic, taking into account the Okun relationship in force in the Spanish regions in the pre-pandemic period. If these two variables follow a similar evolution during the pandemic, it supports the notion that without the ERTEs, the unemployment rate measured by INE would have significantly risen during the pandemic, as predicted by Okun's law. Consequently, the relationship estimated using the conventional variables (INE unemployment rate and GDP) would not have experienced significant changes.

Thus, as indicated in the methodological section, we use the estimated relationship between unemployment and output (Okun's law) from *Model 1* to project the unemployment rate (UR) for the four quarters of 2020, incorporating in the model the information on what happened with economic activity in each region of Spain in that period. Thus, we obtained a measure of what would have happened to the unemployment in each Spanish region during the first four quarters of the pandemic, if Okun's relationship had been maintained during the pandemic. Then we compared those values with the true evolution of UR and with URE in the same period.

Figure 5 shows the results. As seen, in all the regions, the pre-pandemic models predicted a significant increase in unemployment, mainly in the second quarter of 2020 (dotted lines), when the greatest fall in economic activity was recorded. Therefore, the expected values for unemployment rates in the regions predicted a dramatic situation in regional labour markets. On the one hand, from the productive point of view, the projections indicated a significant increase in the number of people who would increase the amount of idle resources in the regional economies, and, on the other hand, from the point of view of workers, a high percentage of employed persons would see their employment and source of income disappear.

When comparing these projections with the actual evolution of the INE unemployment rates in that period, it is observed that the official statistics did not reflect these behaviours, registering in all cases a slight increase in unemployment. In effect, the interannual increase in the unemployment rate (INE) in the second quarter of 2020 was between 0.25 pp and 4.75 pp according to regions (La Rioja and Cantabria, respectively), while the gap between the expected value of the unemployment rate from *Model 1* and the real value measured by the INE ranges according to region between 8 pp and 33 pp in the second quarter of 2020 (Castilla La Mancha and Canary Islands, respectively). Initially, this could be interpreted as a "breakdown" of Okun's law in the regions from the COVID-19 pandemic. As shown in Figure 6, these differences seem to be negatively related to the estimated Okun coefficients (correlation coefficient = -0.79). That is, those regions with the highest Okun coefficients in absolute value, such as the Canary Islands, Catalonia, Extremadura, Madrid and Andalusia, are those with the greatest distance between the UR value projected by the model and the unemployment rate measured by INE, which is logical given that a high Okun coefficient in absolute value implies a strong increase in unemployment in the face of an abrupt fall in economic activity, but in these cases it was not fully reflected in the official statistics.

When we compare these projections with the evolution of the URE variable, it is observed that, although there is not a nearly perfect fit between the two variables in all the regions, in the cases in which this does not occur, the evolution of these variables is much better fit with respect to what was observed with UR, locating the URE variable somewhat above the projections of the models. As Figure 7 shows, the fit between these two variables is positively related to the estimated Okun's coefficient (correlation coefficient=0.75).

The fit between the UR projections and URE is almost perfect in some regions (Andalusia, Asturias, Canary Islands, Catalonia, Extremadura and Madrid), the same regions that have the largest gap between the projected value of UR and the unemployment rate of the INE (UR) and the highest Okun coefficients in absolute value (Figure 7). In these cases, the near perfect fit can have two interpretations. On the one hand, if the application of the ERTE had not been mediated, surely the evolution of unemployment would have shown a trajectory as predicted by *Model 1*, which is reflected in the URE variable; that is, unemployment would have grown significantly. The unemployment rate in the second quarter of 2020 would have been between 17pp and 31pp above the levels observed in almost all of these regions. On the other hand, the nearly perfect fit between the UR projections and URE implies that Okun's relationship continued in force even in the pandemic period.

**FIGURE 5.**
**Unemployment Rate (UR), Expanded Unemployment Rate (URE) and projected UR with pre-pandemic Okun's law**

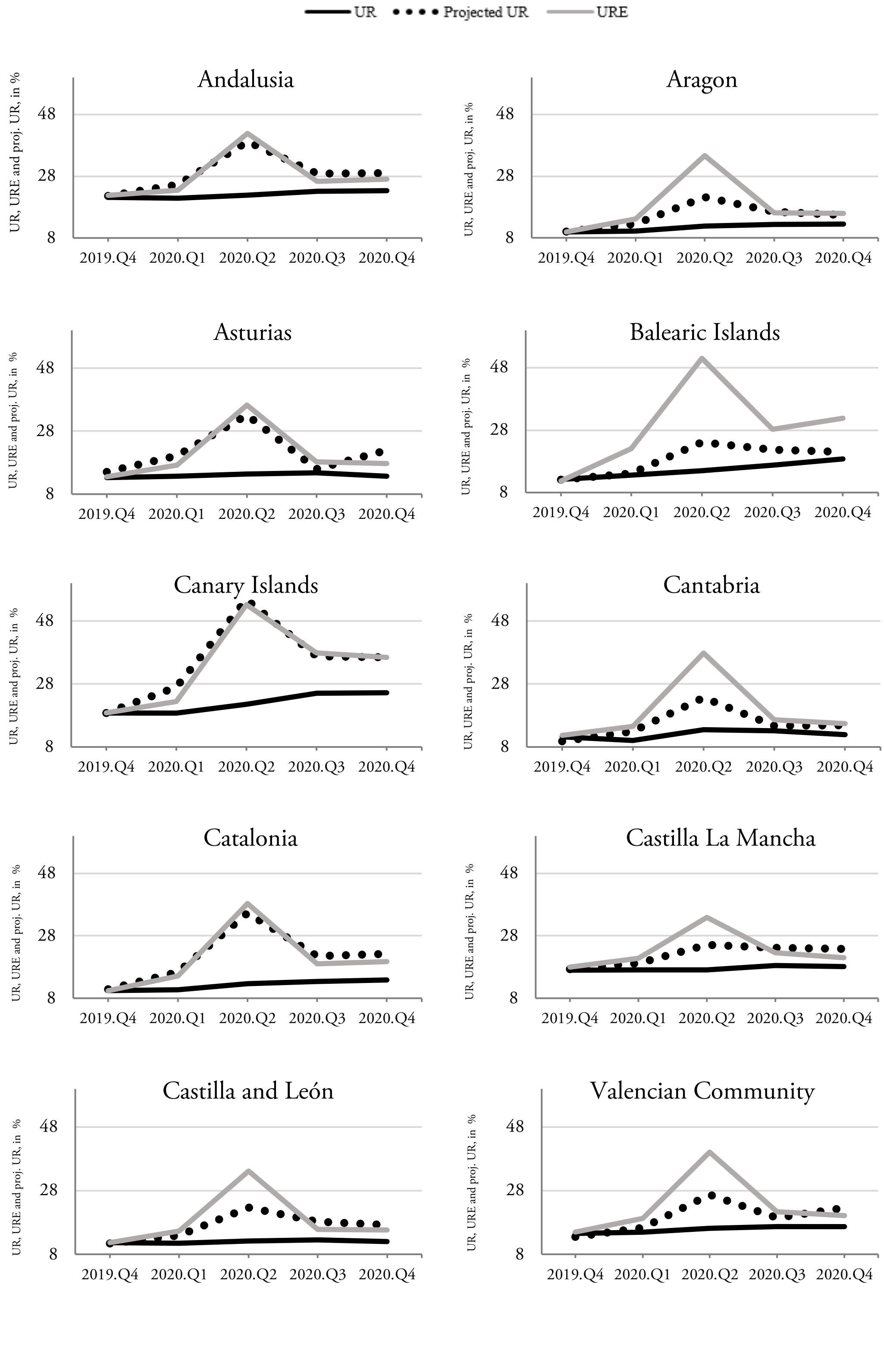
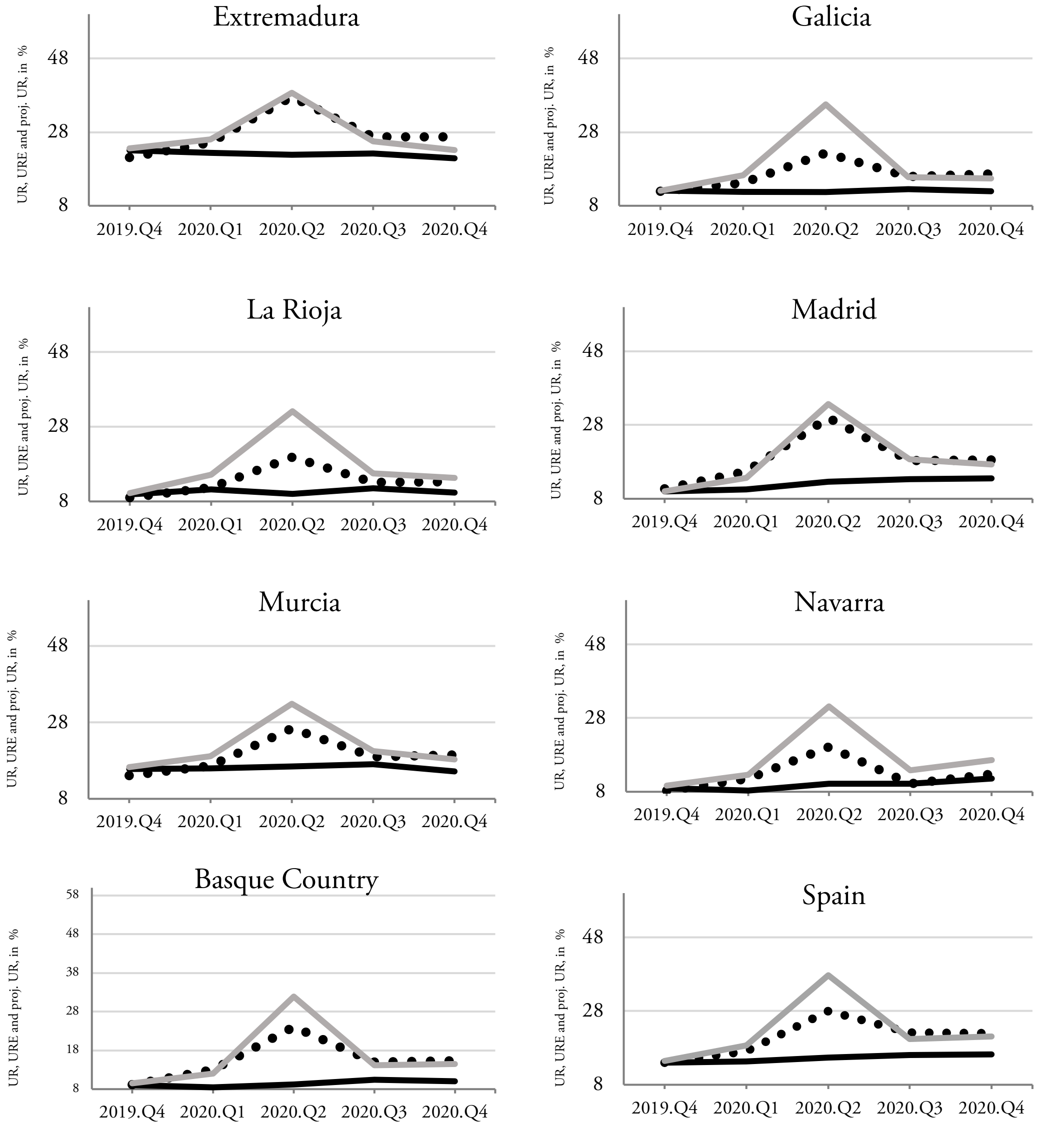


**FIGURE 5. CONT.**
**Unemployment Rate (UR), Expanded Unemployment Rate (URE) and projected UR with pre-pandemic Okun's law**




In the other regions, a gap is observed between the URE variables and the UR projections. Within this group, the regions of Murcia, the Valencian Community, the Basque Country and Castilla La Mancha have the best fit between both variables, with gaps lower than 9 pp in the peak of the second quarter of 2020. All these regions present Okun coefficients at intermediate levels within the range of values estimated for the Spanish regions (Figure 7). In this quarter, the unemployment would have been between 8 pp and 15 pp higher than that recorded by labour market statistics if the ERTEs had not been mediated.

In the rest of the regions, although the gap between the UR projections and the URE variable is greater than 10 pp in the highest peak, in all of them, the unemployment forecast was approximately 10 pp higher than that recorded by the statistics of the INE.

Therefore, despite the fact that the fits between URE and UR projections are not perfect, the observed evolution allows us to affirm that, although official statistics did not demonstrate the validity of Okun's law with the COVID-19 pandemic, in all regions the idle resources increased with the falling GDP, and although perhaps not all would have become strictly unemployed had the ERTEs not been mediated, Okun's relationship continued to be relatively strong in all these regions.

**FIGURE 6.**
**Gap between Projected Unemployment rate and INE Unemployment rate in 2020.Q2 and the Okun's coefficients (*Model 1*)**

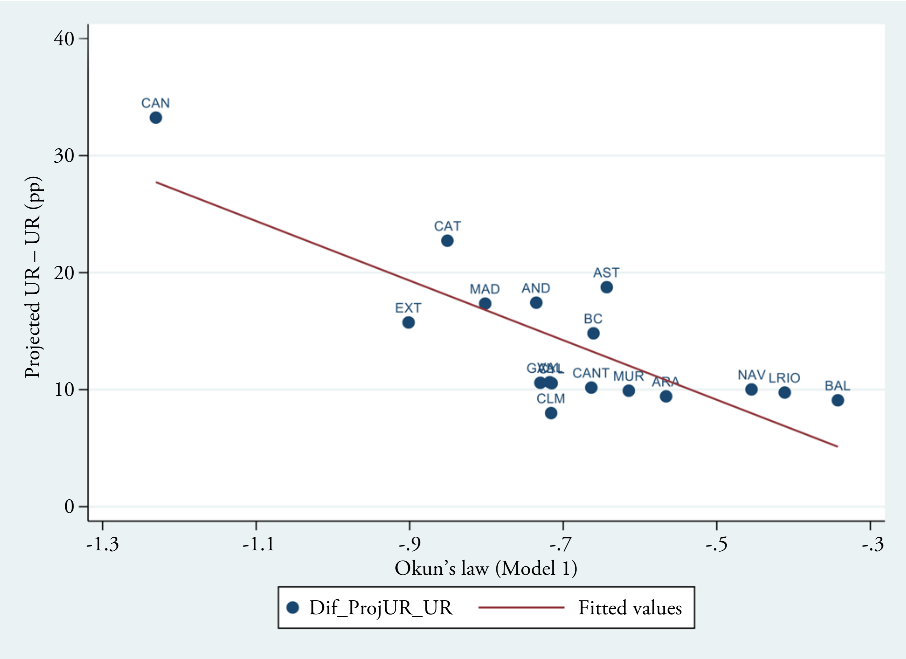
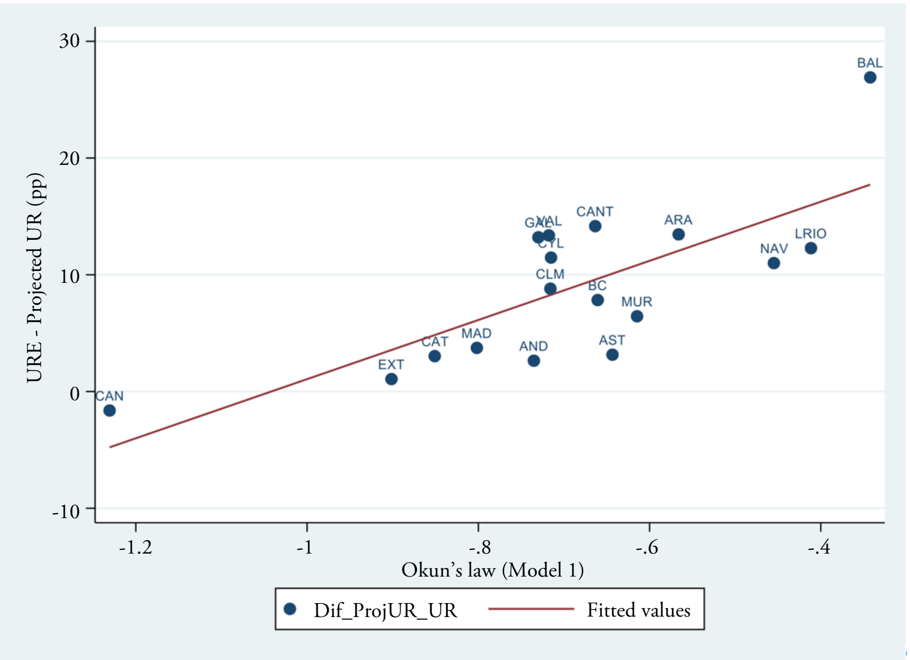



**FIGURE 7.**
**Gap between Expanded Unemployment Rate (URE) and Projected Unemployment rate in 2020.Q2 and the Okun's coefficients (*Model 1*)**



## 5. Conclusions

From this analysis, it can be concluded that, in those Spanish regions where the relationship between unemployment and output were among the strongest in Spain in the pre-pandemic period of COVID-19, if the ERTEs had not been implemented, unemployment would have suffered a dramatic increase in the worst moment of the crisis (2020.Q2), standing between 17pp and 31pp above the unemployment levels recorded by official statistics. Therefore, it is this unemployment "hidden by the ERTEs" that prevented Okun's law from being confirmed during the pandemic. In other regions, where the Okun relationship before the pandemic was somewhat weaker, even though the rise in the unemployment rate would have been somewhat smaller compared to the scenarios mentioned earlier without the ERTEs, it would still not have resulted in a difference of less than 8pp when compared to the official statistics' unemployment rate.

This leads us to think that the estimation of this relationship depends on how unemployment is measured. Under the "promise" of the companies that it would be a temporary situation, the people sheltered by the ERTEs were in general people who became part of the idle resources of the economy. In other words, they were unemployed and receiving unemployment insurance due to the limitation of mobility and the consequent hibernation of the economy in order to prevent the spread of the COVID-19 pandemic.

Therefore, from the productive point of view, it seems that Okun's law continued to be met, that is, the relationship between the variation in economic activity and the variation in idle labour resources continued in force. In addition, if the assumption were made that all the people who took advantage of the ERTEs would have fallen into unemployment if this containment policy had not been mediated, the relationship between economic growth and unemployment would have become even stronger in all regions.

From the social point of view, this situation can be visualized as the implementation of a policy that managed to mitigate the dramatic impact of the fall in the level of economic activity on people, which if the reception of the ERTEs had not been mediated would have meant total loss of their jobs, with the consequent uncertainty about future job placement. In fact, the results of this analysis indicate that if this policy had not been mediated, the unemployment rate would have been, depending on the region, between 8pp and 31pp above the level recorded by the INE statistics.

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## Appendix

**Table. A.1**
**Unit Root test - Augmented Dickey Fuller Test (Null hypothesis: the series has a unit root)**

| | D(UR) | | D(URE) | | D(Log_GDP) | |
|---|---|---|---|---|---|---|
| | **statistic** | **p-value** | **statistic** | **p-value** | **statistic** | **p-value** |
| Andalusia | -1.761 | 0.074 | -11.370 | 0.000 | -10.142 | 0.000 |
| Aragon | -5.523 | 0.000 | -11.308 | 0.000 | -10.237 | 0.000 |
| Asturias | -4.190 | 0.000 | -11.582 | 0.000 | -10.079 | 0.000 |
| Balearic Islands | -1.543 | 0.115 | -10.227 | 0.000 | -9.372 | 0.000 |
| Canary Islands | -5.694 | 0.000 | -9.959 | 0.000 | -9.637 | 0.000 |
| Cantabria | -8.595 | 0.000 | -11.736 | 0.000 | -10.273 | 0.000 |
| Catalonia | -4.134 | 0.000 | -11.313 | 0.000 | -10.147 | 0.000 |
| Castilla La Mancha | -3.434 | 0.001 | -9.246 | 0.000 | -9.703 | 0.000 |
| Valencian Community | -2.414 | 0.016 | -10.615 | 0.000 | -9.990 | 0.000 |
| Castile and León | -2.616 | 0.010 | -11.553 | 0.000 | -10.242 | 0.000 |
| Extremadura | -5.308 | 0.000 | -9.238 | 0.000 | -7.888 | 0.000 |
| Galicia | -1.979 | 0.047 | -11.586 | 0.000 | -9.753 | 0.000 |
| La Rioja | -8.938 | 0.000 | -7.129 | 0.000 | -7.915 | 0.000 |
| Madrid | -5.884 | 0.000 | -7.404 | 0.000 | -10.084 | 0.000 |
| Murcia | -2.205 | 0.028 | -9.262 | 0.000 | -9.921 | 0.000 |
| Navarra | -7.797 | 0.000 | -12.420 | 0.000 | -10.178 | 0.000 |
| Basque Country | -6.011 | 0.000 | -12.072 | 0.000 | -9.973 | 0.000 |
| Spain | -1.895 | 0.056 | -10.830 | 0.000 | -10.120 | 0.000 |

**Notes:** The tests were performed on the first difference of the variables: unemployment rate (UR), extended unemployment rate (URE) and logarithm of GDP (log_GDP). The null hypothesis is rejected when the p-value is less than 0.05. In the tests on D(UR) for Andalusia, Balearic Islands and Spain, the H0 was not rejected, and therefore the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test was also applied, yielding LM statistics of 0.29, 0.17 and 0.30 respectively. Therefore, in both cases the H0 that the series are stationary was not rejected since the statistics are below d 0.463 (5%).

**Table A.2**
**Test on the residuals of Model 1, 2, 3 and 4: Normality, Heteroskedasticity and Serial Correlation (p-values)**

| | Dep. variable: Unemployment Rate (UR) | | | | | | | | Dep. variable: Expanded Unemployment Rrate (URE) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Model 1* | | | | *Model 2* | | | | *Model 3* | | | | *Model 4* | | | |
| | | | Serial Corr. | | | | Serial Corr. | | | | Serial Corr. | | | | Serial Corr. | |
| | Norm. | Het. | LM(1) | LM(4) | Norm. | Het. | LM(1) | LM(4) | Norm. | Het. | LM(1) | LM(4) | Norm. | Het. | LM(1) | LM(4) |
| Andalusia | 0.76 | 0.52 | 0.77 | 0.05 | 0.86 | 0.87 | 0.49 | 0.38 | 0.75 | 0.49 | 0.89 | 0.06 | 0.71 | 0.82 | 0.24 | 0.05 |
| Aragon | 0.37 | 0.68 | 0.73 | 0.58 | 0.35 | 0.68 | 0.99 | 0.74 | 0.88 | 0.28 | 0.99 | 0.30 | 0.31 | 0.48 | 0.03 | 0.07 |
| Asturias | 0.78 | 0.70 | 0.03 | 0.09 | 0.80 | 0.79 | 0.07 | 0.32 | 0.86 | 0.67 | 0.02 | 0.08 | 0.81 | 0.86 | 0.02 | 0.19 |
| Balearic Islands | 0.45 | 0.65 | 0.37 | 0.01 | 0.65 | 0.71 | 0.36 | 0.01 | 0.56 | 0.13 | 0.04 | 0.02 | 0.69 | 0.69 | 0.69 | 0.08 |
| Canary Islands | 0.58 | 0.61 | 0.86 | 0.98 | 0.55 | 0.63 | 0.85 | 0.94 | 0.48 | 0.66 | 0.90 | 0.99 | 0.83 | 0.92 | 0.68 | 0.99 |
| Cantabria | 0.13 | 0.92 | 0.08 | 0.05 | 0.30 | 0.75 | 0.24 | 0.41 | 0.26 | 0.68 | 0.15 | 0.25 | 0.38 | 0.07 | 0.39 | 0.23 |
| Catalonia | 0.71 | 0.09 | 0.47 | 0.61 | 0.91 | 0.80 | 0.11 | 0.29 | 0.63 | 0.18 | 0.24 | 0.35 | 0.79 | 0.89 | 0.61 | 0.73 |
| Castilla La Mancha | 0.61 | 0.48 | 0.67 | 0.13 | 0.73 | 0.41 | 0.42 | 0.16 | 0.33 | 0.84 | 0.05 | 0.05 | 0.39 | 0.65 | 0.56 | 0.07 |
| Valencian Community | 0.89 | 0.87 | 0.12 | 0.10 | 0.98 | 0.08 | 0.23 | 0.01 | 0.61 | 0.55 | 0.03 | 0.02 | 0.50 | 0.91 | 0.13 | 0.40 |
| Castile and León | 0.67 | 0.86 | 0.33 | 0.25 | 0.69 | 0.82 | 0.18 | 0.11 | 0.56 | 0.74 | 0.08 | 0.14 | 0.87 | 0.77 | 0.15 | 0.39 |
| Extremadura | 0.41 | 0.70 | 0.19 | 0.19 | 0.71 | 0.07 | 0.21 | 0.35 | 0.41 | 0.67 | 0.27 | 0.44 | 0.48 | 0.62 | 0.10 | 0.38 |
| Galicia | 0.88 | 0.14 | 0.74 | 0.96 | 0.73 | 0.52 | 0.55 | 0.94 | 0.68 | 0.85 | 0.49 | 0.80 | 0.28 | 0.49 | 0.02 | 0.22 |
| La Rioja | 0.33 | 0.72 | 0.27 | 0.77 | 0.23 | 0.64 | 0.65 | 0.52 | 0.28 | 0.63 | 0.38 | 0.71 | 0.50 | 0.41 | 0.48 | 0.96 |
| Madrid | 0.52 | 0.55 | 0.40 | 0.52 | 0.16 | 0.15 | 0.30 | 0.85 | 0.46 | 0.77 | 0.07 | 0.27 | 0.94 | 0.77 | 0.05 | 0.32 |
| Murcia | 0.58 | 0.42 | 0.21 | 0.09 | 0.65 | 0.78 | 0.11 | 0.05 | 0.49 | 0.39 | 0.40 | 0.09 | 0.48 | 0.63 | 0.65 | 0.09 |
| Navarra | 0.92 | 0.85 | 0.63 | 0.58 | 0.81 | 0.84 | 0.79 | 0.79 | 0.88 | 0.65 | 0.13 | 0.06 | 0.29 | 0.88 | 0.93 | 0.31 |
| Basque Country | 0.78 | 0.72 | 0.45 | 0.62 | 0.20 | 0.95 | 0.39 | 0.62 | 0.79 | 0.39 | 0.44 | 0.82 | 0.59 | 0.90 | 0.35 | 0.73 |
| Spain | 0.70 | 0.92 | 0.41 | 0.85 | 0.42 | 0.84 | 0.98 | 0.98 | 0.66 | 0.04 | 0.03 | 0.21 | 0.89 | 0.27 | 0.96 | 0.49 |

**Notes:** UR is the unemployment rate of the LFS. URE is the expanded unemployment rate (unemployed + people covered by the ERTE). The period in Model 1 and 3 is 2005.Q1 – 2019.Q4 and in Model 2 and 4 is 2005.Q1 -2020.Q4. The residual test are: Normality test Jarque-Bera (Null hypothesis: normality), Heteroskedasticity Test Breusch-Pagan-Godfrey (Null hypothesis: Homoskedasticity), Serial Correlation: Breusch-Godfrey LM Test (Null hypothesis: No serial correlation at up to 1 lag or 4 lags).

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Articles

# Incendios forestales en ecosistemas de la puna húmeda en los Andes de Ayacucho, Perú

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## Resumen:

Esta investigación analiza la extensión y frecuencia de los incendios forestales en el ecosistema de la puna húmeda desde el año 2013 al 2021, identificando las áreas afectadas y determinando las causas con la finalidad de mejorar el manejo de fuego en el departamento de Ayacucho (región andina de Perú). La metodología combina análisis cartográfico, imágenes satelitales y entrevistas semiestructuradas para identificar las causas, consecuencias y alternativas de mitigación de los incendios. Los resultados muestran que las áreas afectadas por los incendios durante los 9 años son muy diferenciadas, siendo el 2020 el año con mayor área incendiada llegando a 2,836 ha lo que representa el 14.89% de la puna húmeda del área de estudio. Además, las áreas incendiadas con mayor frecuencia se repiten entre 7 y 9 veces en diferentes años, con un promedio de ha quemadas de forma reincidente de 182 ha. Las causas de los incendios son netamente de origen antrópico ocasionados por la (i) apertura de nuevas chacras o quema de rastrojo; (ii) quema del ichu para el rebrote de pastos y (iii) por razones culturales. Se concluye que la combinación de metodología de análisis cartográfico, imágenes satelitales y las entrevistas semiestructuras proporcionan información que permite entender las dinámicas del territorio y mejorar el manejo e implantación de políticas territoriales en la mitigación de los incendios.

**Palabras clave:** Incendios forestales; imágenes satelitales; Andes; puna húmeda.
**Clasificación JEL:** O2; O21.

## Forest fires in ecosystems of the humid puna in the Andes of Ayacucho, Peru

## Abstract:

This research analyzes the extent and frequency of forest fires in the humid puna ecosystem from 2013 to 2021, identifying the affected areas and determining the causes in order to improve fire management in the department of Ayacucho (Andean region). from Peru). The methodology combines cartographic analysis, satellite images and semi-structured interviews to identify the causes, consequences and mitigation alternatives of the fires. The results show that the areas affected by the fires during the 9 years are very differentiated, with 2020 being the year with the largest burned area, reaching 2,836 ha, which represents 14.89% of the humid puna of the study area. In addition, the most frequently burned areas are repeated between 7 and 9 times in different years, with an average of 182 ha burned recurrently. The causes of the fires are clearly of anthropic origin caused by the (i) opening of new fields or burning of stubble; (ii) ichu burning for pasture regrowth and (iii) for cultural reasons. It is concluded that the combination of

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cartographic analysis methodology, satellite images and semi-structured interviews provide information that allows understanding the dynamics of the territory and improve the management and implementation of territorial policies in the mitigation of fires.

**Keywords:** Forest fires; satellite images; Andes; humid puna.
**JEL Classification:** O2; O21.

## 1. Introducción

El incendio forestal se define como aquel fuego descontrolado que afecta a los bosques nativos, a las plantaciones forestales y otra vegetación que se desarrolla en tierras forestales de producción y de protección, así como sobre la vegetación silvestre y de ambientes acuáticos emergentes (Minam, 2017); mientras tanto la quema está asociada a una vegetación agropecuaria con fuego bajo control (OTCA, 2015; en Minam, 2017).

A lo largo de la historia el ser humano ha utilizado el fuego como mecanismo de gestión de su territorio en la recuperación de espacios para la agricultura y ganadería, pero también generando problemas graves al ecosistema (Badia et al., 2019). En los Andes del Perú los desequilibrios territoriales están vinculados a las degradaciones de los ecosistemas de la puna húmeda por efectos como de los incendios (ONU, 2009); esto sucede tal como indica Bosques Andinos (2021) a causa de la intervención antrópica ya sea de manera intencional o involuntaria.

El incendio es el fuego no deseado de cualquier origen y se propaga sin control causando daños ambientales, económicos y sociales (CENEPRED, 2020). El fuego un elemento que ha contribuido en la modificación del hábitat de los seres vivos, pero solo los humanos pueden, dentro de los límites, iniciar y detener el fuego a voluntad; así como encender, sostenerlo y propagarlo más allá de su naturaleza (Stephen, 2019).

Una vez iniciado el incendio su propagación está determinado principalmente por tres factores: (a) el tipo de combustible disponible cuyas características aumentan o disminuyen la intensidad y la velocidad de propagación; (b) el clima y la meteorología, relacionado a las estaciones más secas y calurosas, así como las velocidades de los vientos; y (c) la topografía como un factor más constante del territorio, su influencia sobre el comportamiento del fuego es el nivel más visible principalmente las pendientes (CENEPRED, 2020).

El ecosistema de puna húmeda está constituido por vegetación herbácea, dominada por gramíneas de porte bajo, pajonales con gramíneas y algunas asociaciones arbustivas dispersas; en altura generalmente no supera 1,5 metros. Este ecosistema abarca una superficie aproximada de 9.26% (11´981,914 ha) del territorio peruano distribuido en los departamentos de La Libertad, Ancash, Lima, Junín, Pasco, Huancavelica y Ayacucho (Minam, 2018).

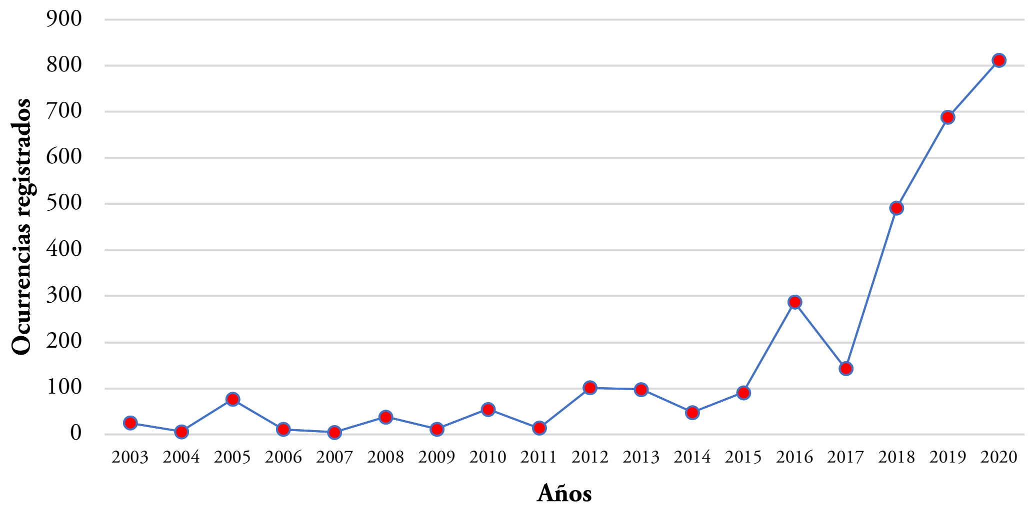
Este ecosistema de puna húmeda del ámbito de estudio seleccionado está considerado por el Gobierno Regional de Ayacucho (GORE, 2013) como área de recuperación por degradación, puesto que ha sido afectado por el sobre pastoreo y los incendios. El primero es la introducción masiva del ganado doméstico que altera superando la capacidad de carga, llegando a producir efectos negativos como la erosión del suelo, compactación del suelo y disminución de la vegetación herbácea (Villalobos, 2013); el segundo, está inmerso a la quema intencional o accidental, generando impactos negativos en el ecosistema como la reducción de la reproducción de las semillas de los pastos naturales, disminución de la capacidad de rebrote, y exterminio de los controladores naturales, como los insectos que combaten las plagas (Torres, 2008).

La investigación analiza los incendios en el ecosistema de la puna húmeda desde el año 2013 al 2021 mediante el análisis de los puntos de calor, áreas incendiadas y entrevistas semiestructuradas a distintos agentes. Los puntos de calor se han obtenido a partir de MODIS (Moderate-Resolution Imaging Spectroradiometer) y VIIRS (Visible Infrared Imaging Radiometer Suite); mientras las áreas incendiadas se han obtenido a partir de imágenes satelitales de Landsat 8 y muestran la extensión de la superficie en hectáreas.

Las entrevistas semiestructuradas contribuyen a conocer las causas, consecuencias y mecanismos de mitigación del incendio desde sus vivencias, percepciones y opiniones de los actores locales de las zonas cercanas a las áreas incendiadas.

Las estadísticas de incendios en Perú muestran un incremento en los últimos años (SERFOR, 2018).el . Los años más críticos fueron 2018, 2019 y 2020 sobrepasando las 800 ocurrencias registrados por INDECI (2020), que en comparación con los años anteriores es hasta 50 veces superior (Figura 1). Para Manta (2017) el 94.5% de los incendios en Sudamérica son de origen antrópico y por causas naturales el 5.5%; pero, en países como Perú y Bolivia, las causas antrópicas pueden representar el 100%, motivados por los cambios en el uso del suelo (especialmente el arrasamiento de bosques para hacer cultivos agrícolas) y la presión antrópica favorecida por la accesibilidad a través de la infraestructura vial y el incremento de las poblaciones humanas.

**FIGURA 1.**
**Incendios forestales en Perú, 2003 a 2020**




**Fuente:** Elaboración propia con información del INDECI (2020).

La mayor ocurrencia de incendios se genera entre los meses de junio a septiembre, caracterizado por la sequía, cuando hay una disminución en el contenido de agua de la vegetación (Manta, 2017; Zubieta et al., 2021). Para evitar programas no efectivos en el manejo de fuego es necesario buscar un consenso entre las partes interesadas (ganaderos y agricultores) para evitar programas no efectivos en el manejo del fuego (Turin y Gilles, 2021). Asimismo, para mitigar los efectos adversos del incendio mediante la gestión participativa se debe enmarcar en acciones en corto, mediano y largo plazo fomentando la reflexión y comprensión de la problemática en la restauración del ecosistema (Amaya y Morales, 2018).

En Perú, CENEPRED (2020) reportó que los departamentos con mayores frecuencias de incendios forestales entre 2003-2020 fueron Cusco, Apurímac, Puno, Ancash, Pasco, seguido por Ayacucho con 136 emergencias de incendios registradas. En el departamento de Ayacucho la puna húmeda representa el 41% de su territorio (GORE, 2013); en el ámbito de estudio de esta investigación, este ecosistema se localiza en las praderas altoandinas, aproximadamente, sobre los 3,700 m.s.n.m. en los distritos de Los Morochucos, María Parado de Bellido y Chuschi con una superficie de 19,000 hectáreas (GORE Ayacucho, 2013). En la cobertura de suelo de la puna húmeda se encuentran asociaciones de especies de pastizales de hasta 80 cm de altura, conocidos comúnmente como "ichu" (*Stipa ichu*) (GORE, 2013).

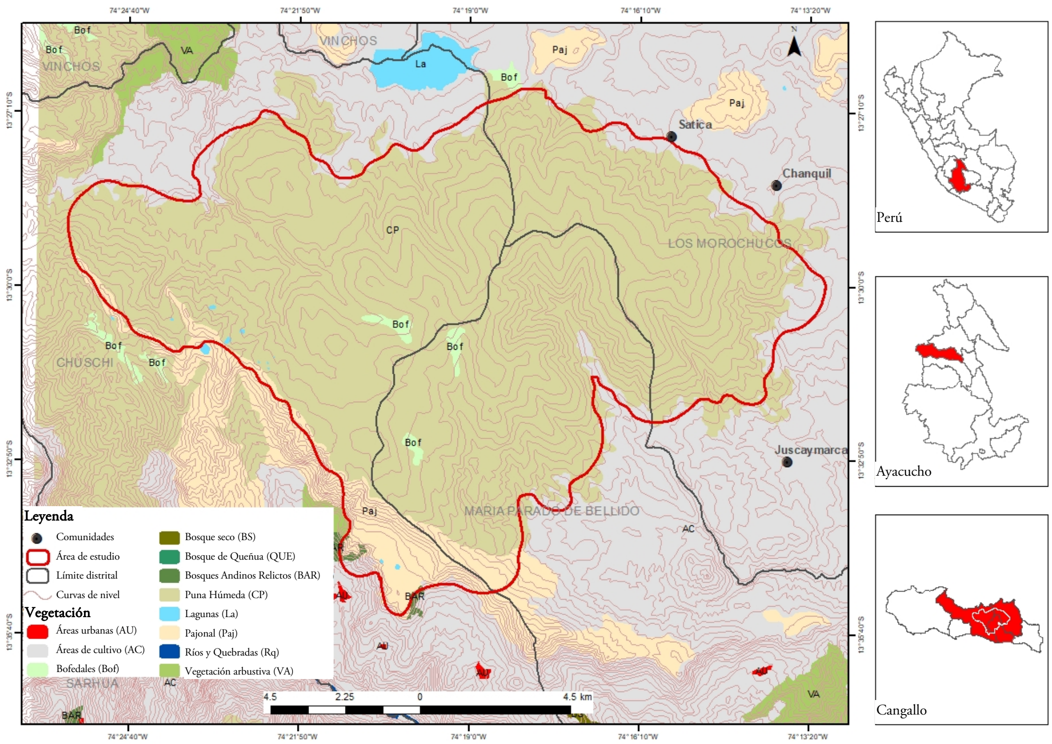
Para el seguimiento de la magnitud del incendio los satélites como, AQUA, TERRA, Landsat 8, brindan información sobre su ubicación, momento de los incendios, área quemada, secas y brotes de incendios forestales, emisiones de aerosoles y gases traza pirógenos. La información brindada por estos satélites tiene diferentes características en términos de resolución espacial, espectral y temporal (USGS, 2022).

## 2. Materiales y método

### Área de estudio

El Área de estudio está ubicada en el ecosistema de la puna húmeda comprendida dentro de los límites administrativos de tres distritos; Los Morochucos, María Parado de Bellido y Chuschi en la provincia de Cangallo del departamento de Ayacucho (Perú) (Figura 2). El área delimitada fue 19,050 hectáreas entre los 3,700 m.s.n.m. a 4,400 m.s.n.m. Se caracteriza por la vegetación dominada por pastizales, conocidos comúnmente como el ichu - *Stipa ichu* (GORE, 2013). Para la delimitación del área de estudio se consideró los siguientes criterios: a) es cabecera de las cuencas de los ríos Macro, Vischongo y Chicllarazu, b) está considerada como zonas de recuperación en la zonificación ecológica y económica (ZEE) del departamento de Ayacucho y c) son áreas con mayor ocurrencia anual de incendios.

**Figura 2.**
**Ámbito de estudio**[1]




**Fuente:** Elaboración propia con datos Instituto Geográfico Nacional del Perú[2] (Límites administrativos), ZEE Gobierno Regional de Ayacucho[3] (curvas de nivel y vegetación)

[1] Visualización en línea del área de estudio. https://www.google.com.pe/maps/@-13.5048291,-74.3598332,12.75z/data=!4m2!6m1!1s1yHakJYqtcTmcQ-slq-YxrpO3nygxzdHP?hl=es

[2] Límite administrativo. https://www.idep.gob.pe/geovisor/descarga/visor.html

[3] ZEE. https://geoservidor.minam.gob.pe/zee-aprobadas/ayacucho/

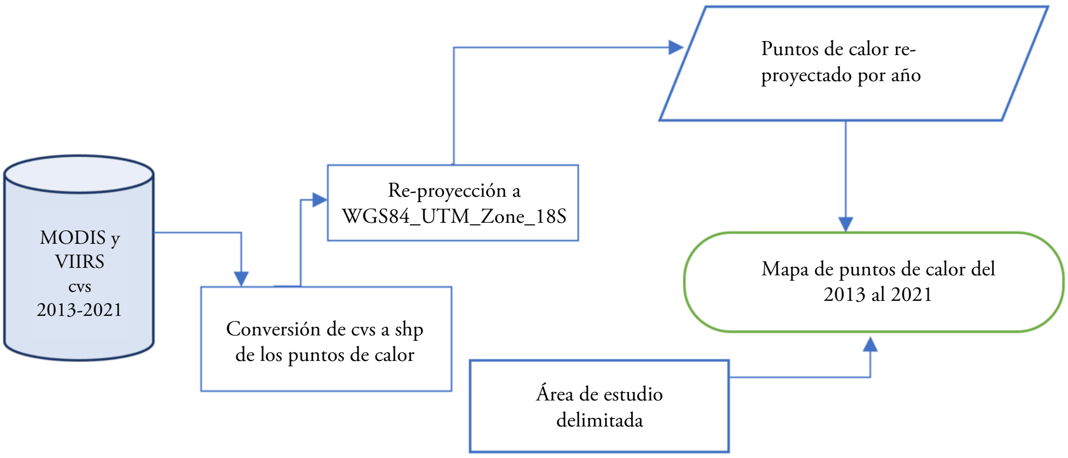
## Análisis cartográfico

La cartografía de puntos de calor se realizó a partir de los sensores MODIS y VIIRS. El primero es un instrumento científico lanzado en órbita terrestre por la NASA en 1999 a bordo del satélite Terra (EOS AM) y en 2002 a bordo del satélite Aqua, su resolución espacial es de 1 km.  Este sensor permite registrar los siguientes aspectos: la temperatura de superficie (suelo y océano), los incendios, el color del océano (sedimentos, fitoplancton), la vegetación global, las características de la nubosidad y las concentraciones de aerosoles (Giglio et al., 2018). El segundo fue lanzado a la órbita en 2011 y en 2017 a bordo del satélite Suomi-NPP. Este sistema satelital es el sucesor de las plataformas Aqua y Terra y, al igual que éstos, recorre 14 vueltas diarias a la Tierra, y registra la capa de nieve y hielo, las nubes, la niebla, los aerosoles, el fuego, las columnas de humo, el polvo, la salud de la vegetación, la abundancia de fitoplancton y la clorofila, su resolución espacial es de 750 m y 375 m. Tanto MODIS como VIIRS toman una medición al día y otra por la noche, aproximadamente siempre a la misma hora local. Sin embargo, VIIRS detecta 3 a 4 más incendios que MODIS a nivel mundial (Giglio et al., 2018; Schroeder & Giglio, 2018).

El sensor MODIS contiene información desde el año 2000, VIIRS desde el 2012 y Landsat 8 desde el 2013. Con la finalidad de uniformizar y comparar los puntos de calor proveídos por MODIS y VIRS, y las áreas incendiadas por Landsat 8, se optó por trabajar desde 2013 a 2021.

Se descargaron las coordenadas de los incendios de los sensores VIRS y MODIS[4]. Esta información se procesó en ArcGis 10.8 generando mapas de puntos de calor para cada año de 2013 a 2021 con los pasos que se muestra en la figura 3.

**Figura 3.**
**Pasos del procesamiento de los puntos de calor de los sensores MODIS y VIIRS del 2013 a 2021**




**Fuente:** Elaboración propia.

En el análisis de las áreas incendiadas, se utilizaron las bandas 5 y 7 de nueve imágenes de Landsat 8, dos[5] por cada año (2013 al 2021) con resolución espacial6 de 30 m, obtenidas del portal de Servicio Geológico de los Estados Unidos (USGS)[7]. Los criterios de selección de imágenes fueron: a) mes con mayor número de puntos de calor reportados por MODIS y VIIRS, b) no presentar errores ni distorsiones; c)

[4] Reporte de datos MODIS y VIIRS. https://firms.modaps.eosdis.nasa.gov/country/
[5] Se compararon dos imágenes sólo para visualizar el área incendiada (un mes antes al incendio y posterior al incendio), sin embargo, se procesó sólo una imagen que es posterior al incendio. Esto debido a que con el índice normalizado del incendio (NBR) del ArcMap se puede realizar el procesamiento con una imagen o más imágenes por año. Además, estas áreas incendiadas se validaron con los puntos de calor de MODIS y VIIRS posteriormente fue complementado con las entrevistas a los pobladores locales.
[6] Resolución espacial: https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites
[7] Portal de Servicio Geológico de los Estados Unidos – USGS: https://earthexplorer.usgs.gov/

tener un máximo de 15% de nubes y sombras en el área de estudio y d) las imágenes para cada año correspondan a los meses de ausencia de precipitación y mayores temperaturas de calor (julio a noviembre) para que las condiciones de vegetación y climáticas fueran homogéneas y permitieran obtener mejores resultados (Chuvieco, 1998 en Rojas, et al. 2018). El procesamiento en el ArcGis 10.8 se hizo con el índice normalizado del incendio (NBR) para identificar la magnitud y áreas afectadas anuales de los incendios. Se calculó como una relación entre los valores NIR y SWIR. La fórmula considerada fue de la USGS[8] (Ponomarev et al., 2021) con una resolución de 30 m (Alcaras et al., 2022).

$$NBR = \frac{Banda\ 5\ (NIR) - Banda\ 7\ (SWIR)}{anda\ 5\ (NIR) +\ Banda\ 7\ (SWIR)}$$

- NIR: near infrared/Infrarrojo cercano
- SWIR: shortwave infrared/Infrarrojo de onda corta

Desde el NBR se estableció un mapa de frecuencia de incendios categorizando en alta (7 a 9 años), moderada (4 a 6 años) y baja (1 a 3 años), es decir, las veces que han sido incendiadas con mayor frecuencia en diferentes años, con un promedio de ha quemadas de forma reincidente.

El seguimiento de áreas incendiadas se puede realizar utilizando imágenes satelitales multiespectrales, estableciendo índices (Alcaras et al., 2022). Sin embargo, estos pueden tener limitaciones determinadas por la presencia de nubes o masas de agua que produzcan ruido. Para evitar estas imprecisiones y optimizar los resultados utiliza *Normalized Burn Ratio* Plus (NBR+) con las bandas Sentinel-2, los resultados muestran alta eficacia sobre todo porque excluye gran parte de las áreas clasificadas incorrectamente como nubes o masas de agua.

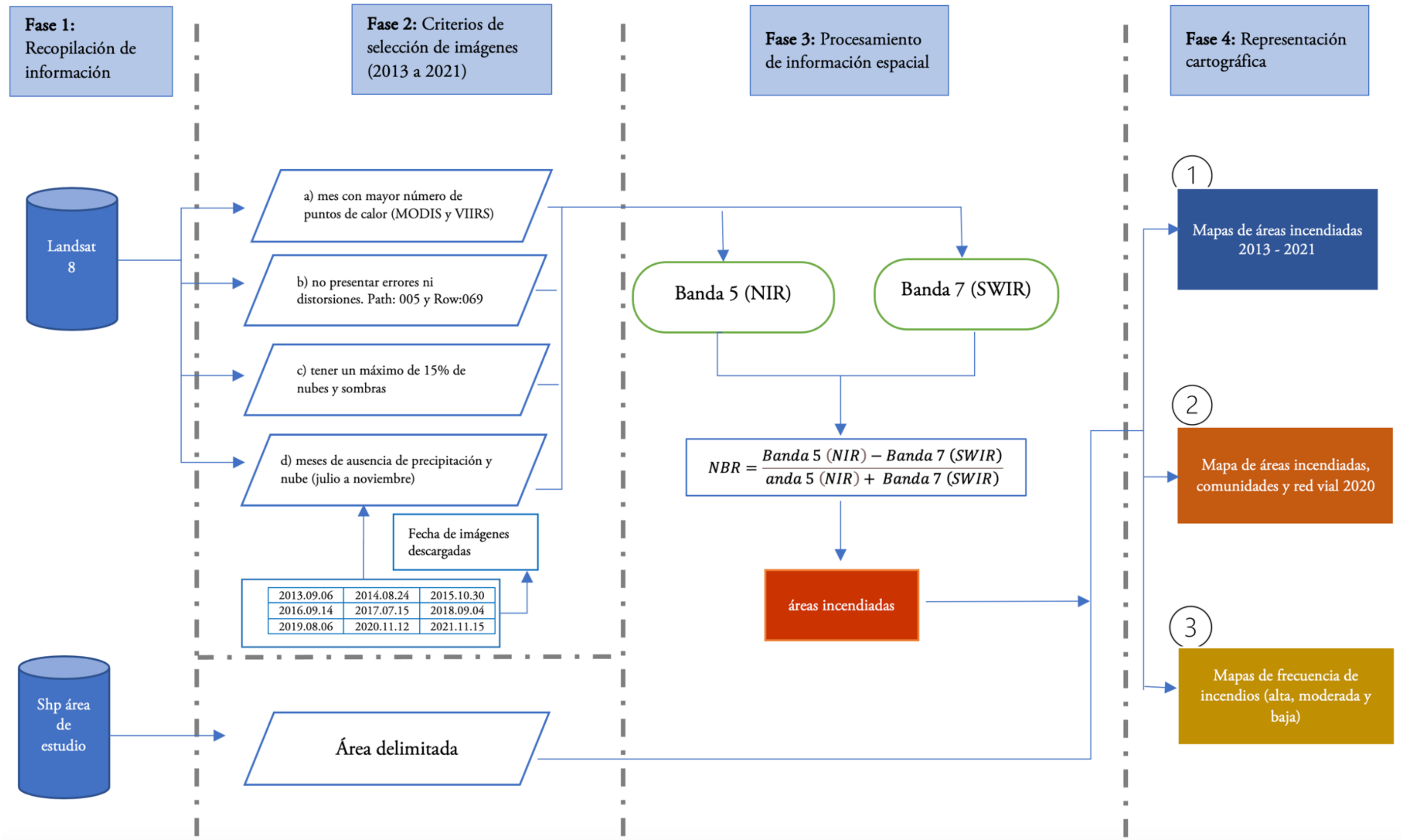
El NBR para Nolé et al. (2022) proporciona información útil sobre la gravedad de los incendios y los procesos de recuperación posterior, basada en métricas espectrales derivadas de MODIS, como la tasa de quema relativizada (RBR), el índice de vegetación de diferencia normalizada (NDVI) y el indicador de recuperación relativa (RRI). A partir de este análisis, el mismo autor afirma que los incendios tienen efectos a posteriori, desde la simple reducción de las funciones del ecosistema, hasta la transición a otros estados. Para lograr estos resultados es necesario considerar las observaciones de píxeles, es decir ¿Cuánta superficie de un píxel debe quemarse para ser detectado por los satélites? Según Riet y Veraverbeke (2022) para Landsat 8, Sentinel-2 y el espectrorradiómetro de imágenes de resolución moderada (MODIS), la detectabilidad se alcanza cuando se quema alrededor de una cuarta parte del área de un píxel; sin embargo, las áreas con poca cobertura de vegetación podrían ser indetectables, generando margen de error en la estimación real del área incendiada.

Los puntos de calor no necesariamente detectan incendios forestales, ya que puede existir márgenes de error con otros focos de calor, tal como indica Giglio et al. (2018); Schroedor y Giglio (2018) señalan que la tasa falsa de MODIS es similar que VIIRS aproximadamente 1.2% Riet y Veraverbeke (2022) señalan que MODIS detecta alrededor de una cuarta parte del área de un píxel quemado; sin embargo, las áreas con poca cobertura de vegetación podría ser indetectable, generando margen de error en la estimación real del área incendiada.

La secuencia metodológica cartográfica muestra cuatro fases (i) recopilación de información, (ii) criterios de selección de imágenes (2013 a 2021), (iii) procesamiento de información espacial y (iv) representación cartográfica (Figura 4).

[8] Fórmula NBR: https://www.usgs.gov/landsat-missions/landsat-normalized-burn-ratio

FIGURA 4.
**Pasos de procesamiento de áreas incendiadas en la puna húmeda del 2013 al 2021**




**Fuente:** Elaboración propia.

## Metodología cualitativa

Desde el enfoque cualitativo se analizó la experiencia subjetiva de las personas, tal como indican Creswell y Poth (2007) y Stake (1995) que la finalidad de este tipo de investigaciones es conocer cómo definen e interpretan su entorno cotidiano. A partir de entrevistas semiestructuradas a los actores locales (ganaderos, agricultores y autoridades)[9] se recogieron las percepciones sobre las causas, consecuencias y alternativas de mitigación de los incendios en la puna húmeda. El diseño de la investigación fue un estudio de caso dirigido a personas de las comunidades rurales con cierta homogeneidad de conocimiento sobre los incendios. Se seleccionó tres comunidades (Satica, Chanquil y Juscaymarca) puesto que son las más cercanas a la puna húmeda, además tienen mayor presencia con sus ganados.

Los participantes fueron seleccionados intencionalmente para obtener más información de la situación o realidad desde las percepciones y opiniones de actores locales (Herrera et al., 2015). Se seleccionaron tres grupos, el primero los ganaderos que frecuentan a la puna húmeda, el segundo los agricultores con áreas de cultivo cercanos a los pajonales y el tercero, las autoridades; quienes participaron voluntariamente. En total fueron 10 entrevistados, cuatro mujeres y 6 varones con edades de 40 a 80 años (Tabla 1).

**Tabla 1.**
**Participantes en la entrevista según lugar y género[10]**

| Ocupación | Satica | Chanquil | Juscaymarca | Total |
|---|---|---|---|---|
| Ganaderos | 2 | 1 | 1 | 4 |
| Agricultores | 1 | | 1 | 2 |
| Autoridades | 2 | 1 | 1 | 4 |

La entrevista a los actores locales se desarrolló en quechua, su lengua nativa, y también en español en algunos casos, estas entrevistas fueron grabadas previa autorización y consentimiento, posteriormente fue transcrito para su análisis correspondiente. El trabajo de campo de la entrevista se desarrolló en dos momentos; la primera etapa del 25 de diciembre de 2021 al 10 de enero de 2022 y la segunda etapa del 10 al 20 de abril de 2022. El tiempo de cada entrevista fue de 15 a 20 minutos.

## 3. Análisis y discusión de resultados

El análisis de los datos reportados por los sensores VIIRS y MODIS en los últimos 9 años (2013 al 2021) han identificado el mayor número de puntos de calor en el año 2020, este incremento coincide con los incendios en el ámbito nacional (Figura 1) muestra un incremento muy fuerte de ocurrencias en los años 2018, 2019 y 2020 (INDECI 2020).

Los meses de septiembre y octubre están marcados por mayor ocurrencia de incendios, justamente los datos meteorológicos no varían mucho con el mes de agosto, siendo los tres meses con menor precipitación, mayores temperaturas de día, bajas temperaturas de noche y vientos más intensos; además coincide con la preparación de tierras para la agricultura donde los pobladores inician a quemar los rastrojos. En la tabla 2 se muestra una acumulación de puntos de calor en los meses de agosto y septiembre reportados de MODIS y VIIRS, pero no la extensión o tamaño de áreas incendiadas, estas cifras de la tabla contribuyen identificar los picos más altos de incendios según los meses del año.

[9] El cargo de autoridad hace referencia a alcaldes o presidentes de las comunidades. Un centro poblado tiene un solo alcalde, pero puede existir varios presidentes que representa a cada pueblo del centro poblado.
[10] Los nombres de las personas entrevistas han sido cambiadas para mantener la confidencialidad.

**TABLA 2.**
**Puntos de calor según meses durante los años 2013 - 2021**

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Enero | | | | | | | | | | |
| Febrero | | | | | | | | | 2 | 2 |
| Marzo | | | | | | | | | | |
| Abril | | | | | | | | | | |
| Mayo | | | | | | | | 1 | | 1 |
| Junio | | | 2 | | | 1 | 2 | | 1 | 6 |
| Julio | | | 1 | | | | 2 | 2 | 1 | 6 |
| Agosto | 1 | 1 | 4 | 1 | 2 | | 7 | 33 | | 49 |
| Septiembre | | | 5 | 4 | | 1 | | 4 | 2 | 16 |
| Octubre | | | 5 | 2 | 1 | | 1 | 20 | 1 | 30 |
| Noviembre | | | | 4 | | | | 4 | 2 | 10 |
| Diciembre | | | | | | 1 | | | | 1 |

**Fuente:** Elaboración propia con datos de MODIS y VIIRS.

Las imágenes satelitales analizadas de los últimos 9 años (2013-2021) reportan que el año 2020 tuvo mayor área afectada (2836 ha) por los incendios, en tanto los otros años no superaron las 100 ha, particularmente el año 2021 fue la más baja con 5 hectáreas incendiadas.

En el año 2021 los incendios afectaron 5 ha, siendo la más baja en los 9 años analizados, aunque para validar las causas de la disminución de incendio queda pendiente realizar investigaciones que argumenten esta particularidad; sin embargo, haciendo una comparación entre los registros de los años anteriores de los incendios, esta área incendiada en el 2021 es el mismo que se incendió en los años 2013, 2014, 2016, 2017, 2018 y 2019, excepto el año 2015.

En el año 2020 fueron afectadas 2,836 ha por los incendios lo que representa el 14.89% del área en estudio; esta cifra es la más alta de los 9 años analizados. Para Busch et al. (2015) las áreas afectadas por los incendios sucesivos tienen un calentamiento continuo que causa una migración de especies de pastizales dejando a las más tolerantes al fuego, es decir, la composición de especies en áreas de incendio sucesivo está cambiando y se espera que continuará cambiando.

Tanto MODIS y VIIRS reportan puntos de calor o incendios activos que detectan cada 24 horas la longitud y latitudlas, sin embargo, Landsat 8 a través de formato ráster muestra el área incendiada y no los puntos de calor, es decir a partir de Landsat 8 se puede saber la extensión del área incendiada. También para VIIRS la detectabilidad de un punto de calor es posible cuando se quema alrededor de una cuarta parte del área de un píxel; por ejemplo, cada pixel de una imagen del MODIS cubre 1000 m y VIIRS entre 375 m y 750 m por lo que sólo son visibles los detalles de mayor tamaño; es decir MODIS detecta un área de 20 ha a 25 ha incendiadas, en tanto VIIRS entre 3.5 ha a 13.5 ha (Riet & Veraverbeke, 2022). Para validar las áreas incendiadas, se superpusieron dos capas, por un lado, los puntos de calor en formato vectorial provenientes de MODIS y VIIRS y, por el otro, las imágenes de Landsat 8. Así incluyendo en el mapa solo puntos de calor provenientes de incendios.

En la figura 5 se muestran las áreas incendiadas delimitadas en Landsat 8 y los puntos de calor detectados por MODIS y VIIRS para el periodo 2013-2021. Los puntos de calor no necesariamente coinciden con las áreas incendiadas y, además, no todos los puntos de calor fueron detectados. Una explicación de ello puede ser que los sensores MODIS y VIIRS toman una medición al día y otra por la noche, es decir dos mediciones cada 24 horas (Giglio et al., 2018; Schroeder y Giglio, 2018), por lo que los puntos de calor generados fuera de este tiempo no son registrados.

En el análisis de la superposición de capas, no necesariamente coinciden los puntos de calor con las áreas incendiadas; en los años 2013 y 2014 sólo una de las áreas incendiadas fue detectada como punto de calor, sin embargo, los sensores de MODIS y VIIRS no lograron detectar otras áreas incendiadas, esto podría ser tal como indica Riet y Veraverbeke (2022) porqué las áreas afectadas tenían poca cobertura de vegetación y la intensidad del calor no fue suficientemente fuerte como para ser detectada.

Para las áreas de frecuencia permanente anual de incendios, se calculó a partir de la suma de las nueve imágenes satelitales que dan como resultado las áreas donde se repiten cada año los incendios que pueden ser consecutivos o en diferentes años (Figura 6).

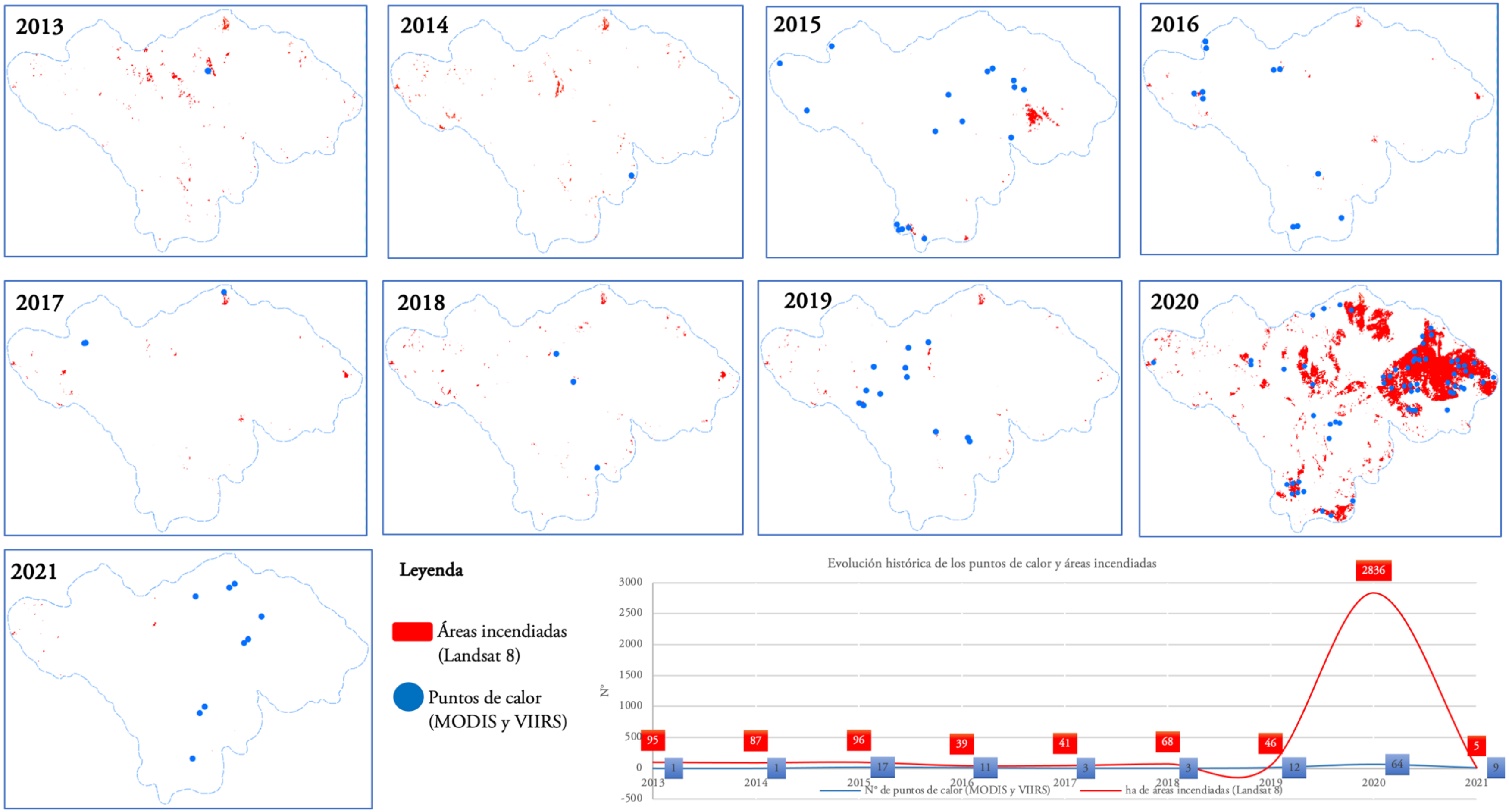
Para la primera categoría de frecuencia "alta", las áreas que han sido incendiadas anualmente en el mismo lugar entre 7 a 9 veces repetitivos se caracterizan por estar cerca a los ecotonos donde inicia la puna húmeda y allí se encuentran los límites de la agricultura (Fotografía 1), es decir chacras de cultivo:

> *Un año en el lugar denominado Tarwiscco, que está muy cerca a la puna hemos quemado rastrojo como siempre cada año, haciendo en los bordes zanja con tractor y cuando de pronto el viento sopló, el fuego de la chacra pasó la zanja y saltó al ichu y no podíamos como apagar, hasta se nos quemó la barba, al apagar el incendio, nos cansamos apagando, desde allí tengo miedo quemar, me asusté, casi se nos escapó y se va a la puna, esto fue en agosto… (Ernesto, agricultor).*

Para el segundo caso "Moderado" las áreas incendiadas se repiten de 4 a 6 años en el mismo lugar, se encuentran no tan cerca al ecotono entre la puna húmeda y las chacras de cultivo, sino más bien en el centro del ámbito de estudio. En el tercero "Bajo" las áreas incendiadas se repiten de 1 a 3 años en el mismo lugar, estas son de mayor extensión de áreas incendiadas.

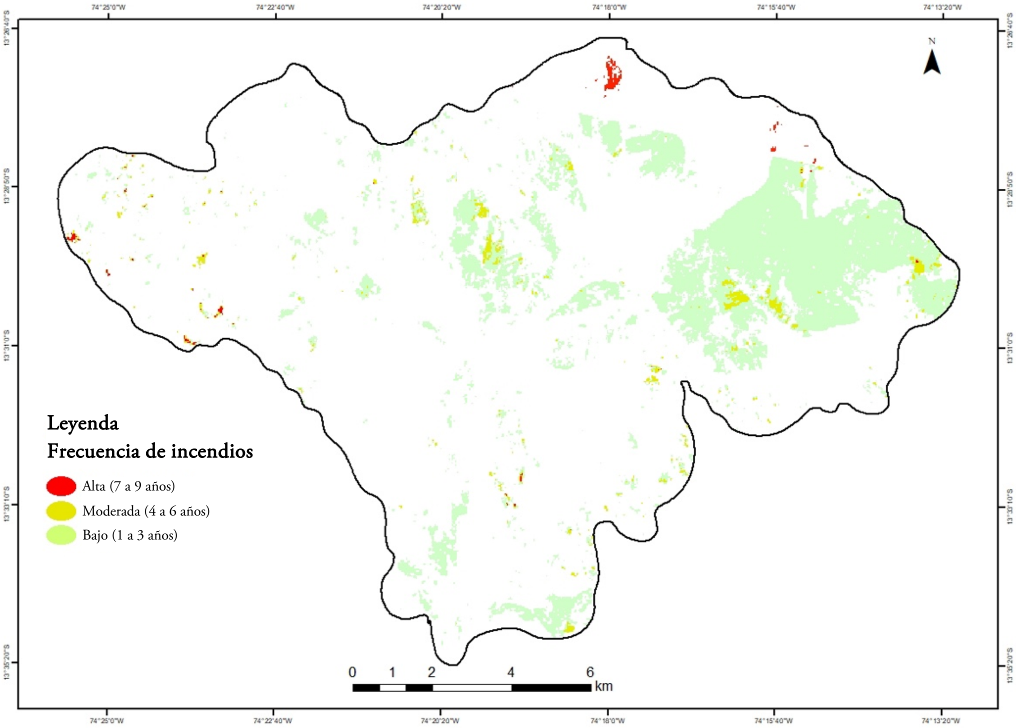
Las comunidades más cercanas a las áreas afectadas por los incendios son: Satica, Pajarescca, Ingalla, Yuraq Cruz, Condoray, Jarhuajara, entre otros; asimismo las redes viales cruzan una parte de la puna húmeda, pero también están próximos a las áreas incendiadas (Figura 7).

FIGURA 5.
**Puntos de calor y áreas incendiadas en el ámbito de estudio desde el 2013 al 2021**



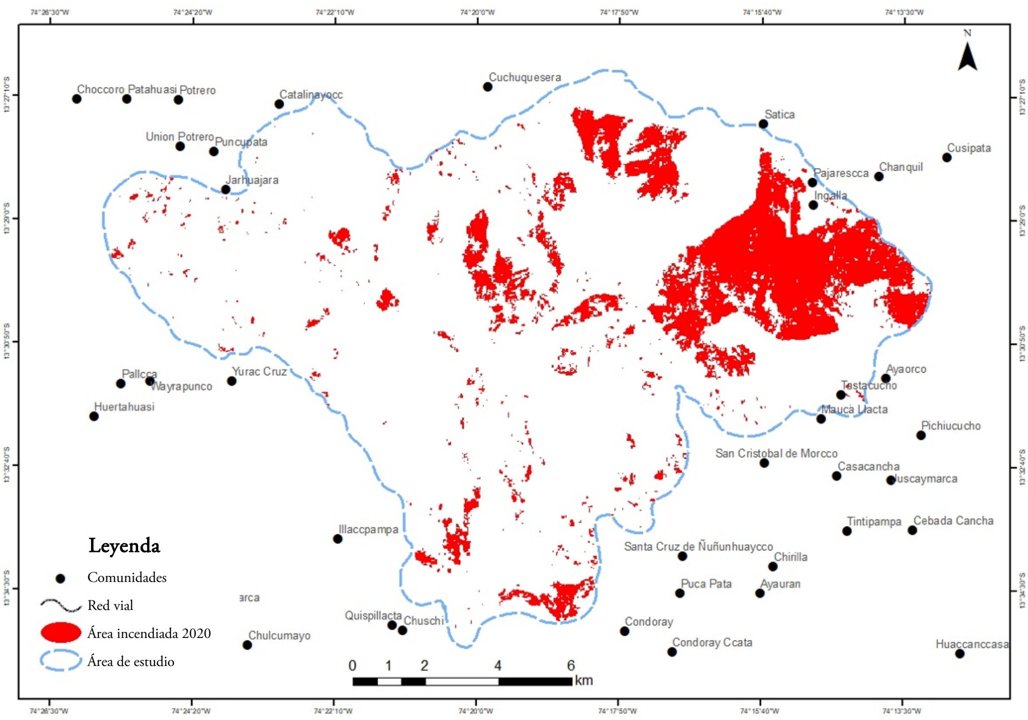

**Fuente:** Elaboración propia con datos de sensores Landsat 8, MODIS y VIIRSS.

**FIGURA 6.**
**Mapa de frecuencia de incendios en el ámbito de estudio**




**Fuente:** Elaboración propia con datos de Landsat 8.

**FIGURA 7.**
**Comunidades y red vial cercanas a las áreas incendiadas en el 2020**




**Fuente:** Elaboración propia con datos de Landsat 8, MTC (2018), INEI (2020).

Las áreas de cultivo cada año han ido acercándose a la puna húmeda, tal como se muestra en la fotografía 1, son parcelas de cultivo de avena resistentes al frío que se cultiva como forraje para el ganado vacuno incrementándose en los últimos años; asimismo para abrir nuevas áreas de cultivo, son quemadas el ichu que en varias oportunidades termina en un incendio.

**Fotografía 1.**
**Ecotono entre áreas de cultivo y la puna húmeda**

**Fuente:** Fotografía de 2013 facilitada por el entrevistado[11] (13°30'50.57"S; 74°14'23.76"O)

Estos incendios, que se repiten cada año en el mismo lugar, están asociados a la apertura de nuevos terrenos de cultivo o quema de rastrojo del mismo terreno; también a la quema del ichu con la finalidad que rebrote para el pastoreo del ganado vacuno y ovino, asimismo también a modo de juego lo encienden los niños, jóvenes y adultos. Posteriormente a los incendios la recuperación de los pastizales para Morante et al. (2002) es un reto, puesto que estas áreas con un nivel de severidad alto llegan a recuperar los pastizales por debajo del 80% de su tamaño.

Si bien las causas de los incendios pueden ser antrópicas o naturales, en el ámbito del área de estudio los entrevistados manifestaron que la causa es netamente antrópica, es decir en ningún caso se ha dado de manera natural como producto del relámpago, por incremento de calor u por otras causas. Los ganaderos y agricultores indicaron que las principales causas de los incendios están inmersas a la quema de rastrojo en las chacras cerca de la puna húmeda:

> *A veces algunos queman a propósito y no pueden apagar, queman mutuycitos (Senna multiglandulosa) para hacer michka (siembra en terrenos pequeños en temporada de sequía) para que los ganados se alimenten (Ernesto, ganadero).*

Para Huffman (2013) el conocimiento tradicional sobre el fuego implica comprender las formas y elementos que interactúan e influyen entre sí. El conocimiento y la práctica tradicional del fuego enfrenta serias amenazas precisamente en el momento en que el cambio climático promete interrupciones en la actividad del fuego que serán problemáticas para las poblaciones locales; la solución será involucrar a los profesionales tradicionales en la prevención de los incendios. Para Lake et al., (2017) las tribus de América del Norte han usado el fuego para promover recursos valiosos, siendo necesario el manejo del fuego en colaboración con asociaciones que comparten conocimientos sobre incendios tradicionales a través de consultas culturalmente sensibles, coordinación y comunicación para generar confianza. Asimismo, Bilbao et al., (2019) señala que las prácticas de incendios por parte las poblaciones locales en la gestión sostenible de la tierra y en la formulación de políticas es limitada. Es necesario comprender el papel del fuego en los

[11] Todas las fotografías fueron facilitadas por Wladimir, que corresponde al incendio del año 2013. Él fue uno de los entrevistados, se dedica a agricultura, apicultura y ganadería; además, labora como personal administrativo en el colegio Los Morochucos.

medios de vida de la población local y su importancia para proteger la diversidad biológica y cultural de los ecosistemas, y no necesariamente excluir el fuego como parte de actividad para la subsistencia.

Los incendios se intensifican en los meses de julio, agosto y septiembre, justamente porque es la temporada de inicio de la preparación de tierras agrícolas para el sembrío, por tanto, las personas que utilizan el fuego en la práctica agrícola queman los rastrojos para luego arar con maquinarias. En este proceso algunos no pueden controlar la quema y es cuando provocan los incendios.:

> *Los incendios se intensifican en los meses de agosto, pero también prenden fuego en los meses de enero a abril, pero se apaga casi inmediato porque el ichu y los pastos están húmedos y la candela no avanza, pero más queman del lado del pueblo de Paccarisqa, porque están abriendo más chacra y sucede todos los años (Rosa, ganadera).*

El ámbito de estudio está organizado en centros poblados, comunidades campesinas y anexos, y la población es netamente rural. Una de las características es el envejecimiento de su población debido a factores como la migración por cuestiones laborales o educativas y por la planificación familiar donde las parejas cada vez tienen menor número de hijos (INEI, 2020). Los entrevistados afirman que los usos de suelo en la puna húmeda para la agricultura o pastoreo son resultado de las quemas y muchas de ellas terminaron en incendio. Esto se validó con las imágenes satelitales, mostrando la ocurrencia anual de incendios, siendo el de mayor magnitud el año 2020. El entrevistado señala que la quema fue una práctica tradicional (desde hace 100 años) para generar un tipo de uso de suelo básicamente para la agricultura y ganadería:

> *Yo tengo 80 años, recuerdo a mi padre cuando era niño decía han quemado la puna y contaba que eso lo hacían también cuando él era niño, entonces la quema siempre ha practicado, pero era poco frecuente, ahora es mucho más (Angel, ganadero y agricultor)*

Tal como señala Vázquez et al., (2022) si bien el manejo de fuego tiene sus raíces en el conocimiento tradicional, actualmente este manejo en la población rural carece de gestión y planificación lo que genera más impactos negativos que positivos. Asimismo, para Smith et al., (2021) los incendios forestales han causado pérdidas de vidas humanas, destrucción de propiedades y transformación ecológica. Sin embargo, el manejo tradicional del fuego puede mejorar las estrategias existentes de mitigación de incendios forestales, siendo necesario la incorporación de conocimientos tradicionales, asimismo el mantenimiento de colaboraciones interculturales.

Las últimas décadas los incendios forestales para Farkhondehmaal y Ghaffarzadegan (2022) han generado un costo considerable a los recursos naturales y vidas humanas, es así para contener a largo plazo hay una combinación de múltiples acciones que apuntan simultáneamente tanto al lado humano como al natural. En el lado humano para Richardson et al. (2022) es probable que el principal impulsor de los incendios es el humano, por tanto, la mayor parte de las acciones se debe dirigir hacia las personas o la población que residen.

Otra de las causas frecuentes de los incendios está vinculada a la alimentación del ganado vacuno y ovino. Se prende fuego en diferentes partes de la puna con la finalidad de quemar el pasto seco para que rebrote en dos a tres meses, así obtener pasto suave y verde para el pastoreo:

> *Lo queman en la puna por el tema del ganado, cuando prenden fuego al ichu o el pastizal, sale o retoña nuevamente y de eso se alimenta los pachus (cordero recién nacido), así se sostienen las familias. Los incendios benefician a unos pocos, más al contrario nos perjudican a la mayoría contaminando el aire que respiramos, matando a las perdices y los zorros bajan a atacar nuestras ovejas al no encontrar alimento; por ello para mí no es necesario quemar (Carlos, autoridad).*

Un estudio de *World Wildlife Fund* (2019) indica que, para la mayoría de las personas, los incendios forestales son sinónimo de desastre. Pero los incendios forestales, planeados y controlados tienen beneficios para el ambiente. Es decir, las quemas controladas o gestionadas pueden ayudar a mitigar un incendio forestal fuera de control, al reducir la carga de combustible. Además, los incendios permiten abrir paso a los árboles jóvenes, sanos y favorecen el rebrote de la vegetación como soporte a la vida silvestre. Los incendios provocados conllevan destrucción de árboles, matan y desplazan a la vida silvestre, alteran los ciclos del agua y la fertilidad del suelo y ponen en peligro la vida y el sustento de las comunidades locales.

Los incendios también son producidos a causa de ciertas creencias o costumbres de la población, alguna de ellas está relacionada con el hecho de encontrar una serpiente y deben matarla, porque si no en la otra vida la persona que fallece no tendrá salvación. Otra de las creencias es cuando se inicia una tormenta con relámpagos para la granizada, se debe hacer humo quemando a partir de hojas húmedas para evitar la caída del granizo:

> *Cuando encuentran una serpiente en los caminos que pasan cerca a la puna, estas entran por escapar debajo de los ichus y la gente lo quema y así también se generan los incendios (Epifania, ganadera).*

Los incendios forestales continúan causando daños a la propiedad, a los medios de subsistencia y al medio ambiente (Mistry et al., 2019). Sin embargo, lidiar con los incendios forestales tiene que ir más allá de la extinción de incendios. Los gobiernos de países con ecosistemas propensos a incendios han comenzado a reconocer las múltiples perspectivas de la quema y la necesidad de involucrarse con las comunidades locales y sus prácticas. En países como Venezuela y Brasil, a través de la quema prescrita y la apertura de un diálogo sobre el manejo del fuego entre las agencias gubernamentales y las comunidades locales, han conseguido reducir la extensión de los incendios forestales. Los incendios pueden causar impactos adversos significativos para la sociedad y el ambiente; siendo el tiempo y el clima los principales factores que juegan un papel importante en la modulación de los incendios (Richardson et al., 2022).

Particularmente el incendio en el año 2020 según reportes satelitales afectó a grandes extensiones de pastizales en la puna húmeda del ámbito de estudio, esta particularidad solo fue en el año 2020 y justamente coincide con la crisis sanitaria de la pandemia generado por la COVID 19. También a partir de los testimonios el año 2020 tuvo las mayores áreas incendiadas, esto debido a la apertura de nuevas chacras o áreas de cultivo que realizaron las familias que regresaron de las grandes ciudades hacia los pueblos o rurales:

> *Por el virus regresó mi primo y vive por Chanquil, ellos empezaron abrir nuevas chacras cerca a la puna y se hicieron vencer con el fuego…han tenido problemas con las comunidades afectadas por esa situación (Gertrudes, ganadera).*

Un estudio realizado por el Banco Interamericano de Desarrollo (2022) señala que el retorno masivo de las personas de la ciudad al campo o zonas rurales pudo haber generado presión sobre los recursos naturales. Para afirmar dicha hipótesis se realizó un análisis evaluando la posible relación entre las migraciones debido a la COVID-19 y el aumento de la deforestación ocurrida en el año 2020 en la Amazonía peruana. En este alcanzó más de 200 mil hectáreas, siendo la tasa más alta de los últimos 10 años; sin embargo, no fue posible establecer una correlación directa, pero existe la posibilidad que haya una relación entre el aumento de la deforestación y la migración hacia esas zonas, pero no necesariamente de retornantes por la pandemia, sino también de los propios pobladores locales.

Las consecuencias de los incendios en la puna húmeda, ocasionados por acciones humanas son diversas, desde la pérdida de vida de la fauna silvestre hasta la extinción de la flora.

> *Hace como dos años se incendió toda la puna de los lugares de Qatunpallca y Uchuypallqa y no descubrieron el autor, así nada más se quedó, cuando todo está quemado las vicuñas no tienen nada que comer, pero también se quema las lagartijas, serpientes, zorro, zorrino, perdiz, Liccles, entre otros animalitos (Angel, agricultor y exautoridad).*

La severidad del fuego afecta fuertemente a las aves, para la mayoría de las especies fue negativo la cantidad de bosque severamente quemado en el paisaje, sin embargo, son muy pocas las especies que se recuperan en poco tiempo después de los incendios (Lindenmayer et al., 2014). Pero los efectos del incendio no solo tienen impactos positivos o negativos en las aves, sino también en los polinizadores, que tienden a incrementar su presencia después de un incendio forestal (Carbone et al., 2019). Pero esto sucede en intervalos de tiempo largo, en tanto en intervalos cortos de fuego pueden amenazar a los polinizadores y especialmente a los lepidópteros.

La fotografía 2 refleja el preciso momento del incendio en la puna húmeda de Los Morochucos en el año 2005, la población de los pueblos aledaños llegó a la zona a intentar apagar haciendo denodados esfuerzos logrando controlar después de 5 horas de trabajo.

**Fotografía 2.**
**Pobladores en el intento de apagar el incendio en la puna**

**Fuente:** facilitado por Wladimir. (13°30'25.23"S; 74°14'50.81"O)

Los incendios sucesivos que se producen anualmente no solo afectan o terminan con la vida de la fauna, sino también cada año el crecimiento de los ichus no logra alcanzar su tamaño promedio, siendo cada vez más pequeño, así mismo algunos de ellos desaparecen porque el fuego llega hasta la raíz y los suelos van quedando desprotegidos:

> *Cuando era pequeña había mucho ichu, por las quemas que ocurre cada año ha disminuida de cantidad y tamaño, porque el fuego llega hasta la raíz algunos ya no vuelven a rebrotar [….] yo tenía miedo de quemar, mi mamá me asustaba y ni siquiera agarraba fósforo (Rosa, ganadera).*

Las praderas abandonadas para Bonanomi et al. (2022) promueven la propagación de pastos altos, lo que reduce la diversidad de plantas y aumenta el riesgo de incendios forestales, de esta forma la quema deviene efectiva al contrarrestar tales efectos negativos. El efecto de fuego sobre la composición y estructura de las comunidades arbustivas en pastizales semiáridos puede transformar de estado de matorrales a pradera, asimismo, la vegetación, el funcionamiento del ecosistema y la economía de la región (Hebbelmann et al., 2022). En determinados territorios los pastizales sin pastoreo son un riesgo alto, por ello Vaverková (2022) afirma que la vegetación representa una fuente de energía renovable y sostenible. Sin embargo, es necesario emplear métodos adecuados de manejo de pastizales como pastoreo con animales para minimizar el riesgo de incendios.

Existe canciones que practican las poblaciones en su lengua nativa el quechua, referidos a los incendios manifestando su disconformidad y frustración.

| Quechua | Español |
|---|---|
| Urqupi ichu kañasqa<br>Qasapi ichu kañasqa | Ichu incendiado en la puna<br>Ichu incendiado en la loma |
| Hinallaraqchu rupachkan<br>Hinallaraqchu mismichkan | ¿Todavía estará incendiándose'<br>¿Todavía estará humeándose? |
| Hinaya rupallachkachun<br>Hinaya mismillachkachun | Que siga incendiándose<br>Que siga humeándose |
| Warma wiqiywancha parqusaq<br>Warma wiqiywancha tasnusaq | Yo mismo con mis lágrimas irrigaré<br>Yo mismo con mis lágrimas apagaré |

**Fuente:** Anónimo, traducción propia, validada por los entrevistados que cantaron[12], para escuchar el audio ingresar al enlace https://drive.google.com/drive/u/0/folders/1DoyocMhvsnsQbwBqRjT_vdsl9Kf0UBMv

Las soluciones para mitigar los incendios en la puna son diversas desde la opinión de los agricultores y ganaderos¸ algunos plantean levantar muros de roca o corrales de piedra juntamente con las zanjas, estos evitarían la propagación del fuego hacia otras partes:

> *Es necesario hacer muros de piedra y al costado una zanja de piedra en linderos estratégicos para evitar que los incendios avancne y lleguen a las plantaciones (Angel, agricultor y exautoridad).*

Según la Ley Forestal y de Fauna Silvestre N° 29763 en el artículo 150 (2015) las denuncias de infracciones y delitos en materia forestal y de fauna silvestre se canalizan a través del Ministerio Público, el Osinfor, el OEFA o la autoridad regional forestal y de fauna silvestre, según corresponda. Además, provocar incendios forestales y realizar quemas de los recursos forestales son consideradas faltas muy graves y el Código Penal sanciona con pena privativa de la libertad de 4 a 6 años, mientras que la multa administrativa oscila entre 10 y 5,000 Unidades Impositivas Tributarias (UIT). Sin embargo, estas leyes no se cumplen para los responsables que generan incendios. Aunque los incendios generados intencionalmente son tipificados como delito, el uso del fuego para la agricultura tradicional, la ganadería y la silvicultura es muy importante para los agricultores de los países en desarrollo (Martínez et al., 2016).

## 4. Conclusiones

El análisis de los puntos de calor, las áreas incendiadas y las entrevistas semiestructuradas a distintos agentes, han permitido conocer la distribución espacial de los incendios y entender la causalidad y ofrecer posibles soluciones.

La superficie de las áreas afectadas por los incendios en el ámbito de estudio a partir del análisis de las imágenes satelitales de Landsat 8 desde el año 2013 al 2021 son muy diferenciadas, siendo el año 2020 con el mayor número de hectáreas incendiadas llegando a 2,836 ha que representa el 14.89% de la puna húmeda del área de estudio. Este incremento coincide con la pandemia del COVID 19 donde hubo migración masiva o de retorno de la ciudad al campo, estas personas según las entrevistas provocaron incendios por intentar abrir nuevas áreas de cultivo.

Las causas de los incendios son netamente de origen antrópico ocasionados por la (i) apertura de nuevos chacras o quema de rastrojo cerca a la puna húmeda; (ii) quema del ichu para conseguir rebrote de pastos suaves y verdes para la alimentación de los ganados y (iii) por razones culturales.

La combinación de análisis cartográfico y metodología cualitativa permitió identificar las áreas afectadas anualmente por los incendios forestales; pero también los agentes causantes de los incendios en la puna húmeda de los Andes de Ayacucho posibilitando toma de decisiones para su mitigación. Los incendios en la puna húmeda en los Andes de Ayacucho son un problema para las comunidades, puesto

[12] La versión del audio grabado se puede escuchar en quechua cantado por Juana Cisneros Castro y Angel C. Aronés Roca

que se pierde cada año hectáreas de pastizales como el ichu; asimismo moviliza a la población para apagar de manera rudimentaria poniendo en riesgo la vida de las personas. Esta situación evidencia que es necesario un plan de manejo del fuego para las áreas afectadas.

Las posibles soluciones para mitigar los incendios que se plantean son: (i) levantar muros de roca o corrales de piedra juntamente con las zanjas, estos evitarían la propagación del fuego hacia otras partes; (ii) hacer cumplir la Ley Forestal y de Fauna Silvestre N° 29763 el artículo 150 que indica provocar incendios y realizar quemas de los recursos forestales son consideradas faltas muy graves cuya sanción es la pena privativa de la libertad de 4 a 6 años, mientras que la multa administrativa oscila entre 10 y 5,000 unidades impositivas tributarias (UIT); (iii) capacitar y sensibilizar a las entidades competentes en el tema sobre prevención de incendio a toda la población de las comunidades y (iv) activar el derecho consuetudinario con normas establecidas por los comuneros castigando a los responsables de los incendios con el decomiso de su ganado vacuno y haciendo pagar la multa.

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Articles

# The statistical grid as a unit of observation and analysis: Andalusia, Spanish region case study

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## Abstract:

Units of observation with reduced dimensions and regular geometry have been increasingly generated in a recent, albeit already steady, trend towards further territorial data disaggregation. In this line of research, the present study reports the results of using the spatial distribution of population data and built-up areas at a high level of territorial data disaggregation with reduced dimensions and with a homogeneous observation unit by applying a regular grid consisting of 250-m square cells. The main objective was to show the results and advantages of working at a high level of spatial data disaggregation. This approach provides a more comprehensive knowledge of the territory and allows for a more accurate analysis of spatial patterns in the different variables under study, thereby enhancing the quality of decision-making processes.

**Keywords:** Grid; population; cadastre; building; dwelling.
**JEL Classification:** I31; I14; R23.

## La malla estadística como unidad de observación y de análisis. El caso de Andalucía

## Resumen:

Existe una tendencia reciente, aunque ya consolidada, encaminada a la búsqueda de una mayor desagregación territorial de la información. En este contexto, la generación de unidades de observación de dimensiones reducidas y geometría regular ha ido tomando fuerza. Así, en este artículo se muestran los resultados de la utilización de datos de distribución espacial de la población y del espacio construido en un nivel de desagregación territorial de dimensiones reducidas y con una unidad de observación homogénea con una malla regular compuesta por celdas cuadradas de 250m de lado. El objetivo principal es mostrar los resultados y las ventajas que reporta trabajar con una mayor desagregación espacial de la información. El resultado es un conocimiento más exhaustivo del territorio y la posibilidad de estudiar de una forma más precisa los patrones de comportamiento de las distintas variables analizadas.

**Palabras clave:** Malla estadística; población; catastro; edificio; vivienda.
**Clasificación JEL:** I31; I14; R23.

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## 1. Introduction

Spatial analysis, like cartography, is a discipline that relies on two essential facts to represent information: all elements have a non-arbitrary location in space and defining and characteristic thematic attributes. Thus, in general, the information represented on a map and the observation unit used as a reference to process and represent this information must be defined. Physical data are represented using environmental or natural divisions, such as bioclimatic units, geographic districts, or others, depending on the thematic information. Socioeconomic data is usually aggregated in different administrative units, depending on the scale of representation and on the available data and is thus far more common at the provincial or municipal level.

The selected spatial scale (or level of detail) and observation unit can modify the perception and analysis of spatial patterns of the represented variable by modifying the quantitative data and their effect on the data distribution, which varies with the scale of analysis. Scale and zone effects are known in spatial data analysis as the Modifiable Areal Unit Problem (MAUP), which expresses how the correlation between two phenomena distributed in space can dramatically change with the size and shape of the spatial units used to measure the phenomena (Goerlich and Cantarino, 2012). Therefore, a higher spatial disaggregation of these data enables a more reliable and accurate analysis of territorial patterns.

Dasymetric maps with homogeneous units of observation have long been prepared for a wide range of applications and can be defined as choropleth maps where the areas with statistical information are represented as homogeneous areas, assuming that the represented data are homogeneously distributed throughout the territory. Quantitative data are expressed using superficial symbols in the units where the variable takes a uniform value. Thus, dasymetric maps with homogeneous units, generally cells, have been generated to present and analyze not only environmental data but also population distributions in units other than merely administrative divisions. The dimensions of these homogeneous units have not always been the same and, in some cases, have had to be adapted to the resolution of the corresponding CORINE Land Cover (Gallego, 2010).

Thus, in a recent trend towards further territorial data disaggregation, this information is often represented at the census tract level. However, this approach has two fundamental drawbacks. On the one hand, census tract boundaries are frequently changed to adapt to the needs of managing electoral processes. On the other hand, the spatial heterogeneity of these divisions is inconvenient due to the wide differences in their surface dimensions, which are often too large (Mora and Marti, 2015). Moreover, broadly speaking, "the unit of analysis, 'census tract,' does not ensure any homogeneity in terms of socioeconomic or demographic characteristics of its individuals, nor any uniformity in relation to the urbanization or shape of the territory covered by this tract" (Enrique, 2013, p. 5).

Considering the above, conducting a comprehensive analysis of the spatial distribution of socioeconomic variables requires not only disaggregating the data to the municipal level but also overcoming the rigidity of administrative boundaries in general, which greatly hinder the ability to relate data from different sources.

The Sustainable Development Goals, structured under Agenda 2030, define a plan of action for people, planet and prosperity, in order to achieve a sustainable future for all. Goals aiming to improve daily life conditions such as health, education, employment while reducing poverty, inequality, climate change, environmental degradation, and reaching prosperity, peace or justice require an integrated and indivisible balance of the three dimensions of sustainable development: the economic, social and environmental. Thus, goals are interrelated and interlinked, working with spatially disaggregated information allows us to approach territorial disparities on health, employment, income, housing characteristics, size, construction quality, etc. in greater detail.

## 2. Background and rationale

To clearly understand the territorial unit problem, we must first analyze spatial data disaggregation. This technique delves into the factors that affect the different phenomena that may occur in a territory. This subject has long been studied, and its main difficulty involves spatial data referencing. Currently, a very large volume of information is available, but its geocoding remains a difficult task. This referencing is frequently performed by correlating data with administrative units. In general, this approach is followed when analyzing and reporting socioeconomic data. The most disaggregated administrative division has usually been the municipality. Information at a more disaggregated level of detail is difficult to find. Therefore, this process must be analyzed in depth, studying methods for a higher level of disaggregation of statistical information. In this context, Eurostat has been promoting the development of a grid to disaggregate European population data as much as possible. The second step consists of integrating, together with demographic data, all statistical data on socioeconomic and environmental variables in a common unit of observation and analysis (Goerlich and Cantarino, 2012).

The European Forum for Geography and Statistics (EFGS) has been developing, with the support of Eurostat, the ESSnet projects, Geostat 1A, 1B, 2, and 3. The first two projects were aimed at developing methodological guidelines for transferring the 2011 population and housing census results to a harmonized and common 1-km$^2$ cartographic grid, following the criteria established in the Infrastructure for Spatial Information in the European Community Directive (INSPIRE) (EFGS, 2013; Enrique *et al.,* 2013b). The second project, 1B, aimed at representing data from the respective 2011 census, and the main purpose of the projects Geostat 2 and 3 was to foster statistical and spatial data integration to enhance the quality of socioeconomic and environmental analyses (EFGS, 2012; 2013; 2017).

This initiative has a global scope, beyond the European Union; the United Nations is also involved, through its Committee of Experts on Global Geospatial Information Management (UN-GGIM), an intergovernmental body of the United Nations Statistics Division (UNSD). These key experts have been working to integrate statistical and geospatial data to analyze territorial phenomena that may be relevant to the population more accurately (Petri, 2014). Studies conducted primarily in different European countries have initially delved into developing methods for implementing population data referencing at a high level of disaggregation, such as that of a 1-km$^2$ cell. For this purpose, various techniques have been used, depending on the organization of the basic data in each country and on the corresponding decision-making. Ongoing research is aimed at developing techniques for more reliably and accurately georeferencing the entire population.

The EFGS organizes annual conferences. In the initial editions, research efforts were focused on improving methods for georeferencing population data. Some studies have detailed these tasks based on a top-down approach (Duque, 2013; Goerlich, 2013; Bresters, 2014; Chiocchini *et al.,* 2014; Freire and Halkia, 2014). These studies usually start from municipal data, or information associated with some inframunicipal administrative division in the case of census tracts and combine this information with some data on land use to estimate the real location of the population within the territory. In turn, some studies have specifically analyzed how to treat demographic data that are difficult to georeference due to difficulties in finding references for their location (Kraus and Moravec, 2013). Other studies have presented the possibility of using bottom-up approaches and source data at the highest level of disaggregation, such as that of the building entrance, assigning them to the corresponding cell through the respective data assignment processes (Duque, 2015; Corcoran, 2017) or through hybrid techniques, combining bottom-up and top-down approaches, most often to complete the allocation of the population data that have not been referenced in the first step (Bueno and D'Antona, 2013; Enrique and Ojeda, 2013, Nieves *et al.*, 2021 and Darin *et al.*, 2021).

Spatial referencing at high levels of population data disaggregation is currently well established, at least for 1-km2 cells. The current trend is to integrate this population information with various other data. This is the fundamental purpose of this approach, and progress has been made over time although some data are difficult to reference due to difficulties in either managing or accessing them, or even knowing their location. In this sense, the power of analyses that integrate statistical data will likely lead to the need for referencing all information in the near future. Accordingly, this article shows the usefulness of performing analyses with spatially referenced information at a detailed level and delves into techniques for gathering data organized in this way. The themes on which it works are very varied. Thus, and to date, some studies have correlated data in spatial aggregation and disaggregation approaches as a tool for assessing environmental impacts in processes that help to achieve the United Nations Sustainable Development Goals (SDG) (Scott, 2017), whereas other studies have analyzed the integration with urban (Trainor, 2017), employment (Poelman, 2017), infrastructure (Santos, 2013), or traffic and mobility (Piela, 2014) data. Other studies have also integrated demographic and statistical data on land-use planning (Vala *et al.,* 2015). Some experiments stand out, such as those referencing information extracted from cell phone geolocation and information emitted by them, thereby monitoring spatial behavior patterns of populations and their daily mobility patterns (García *et al.,* 2013; Kuzma and Nikić, 2015; Salas *et al.,* 2015; Condeço *et al.,* 2018). In other experiments, demographic data have been integrated with information on production activities, studies showing the potential of a Geographic Information System (GIS) for these activities (Bao and She, 2014).

Based on the above, this article describes a set of experiments performed in Andalusia (Spain) in which demographic and cadastral data retrieved from administrative records were analyzed, referencing a series of phenomena in the territory showing the corresponding spatial distribution patterns. These experiments illustrate the power of analyzing data disaggregated into small and homogeneous cells in both shape and size.

## 3. Methodology

The tasks described in these projects are executed based on demographic and cadastral information for the Andalusia region. There are several million records of graphic and alphanumeric information reporting on population and building characteristics. PostgreSQL stores in a simple way all the data that compose the database and allows to systematize the processes of consultation and management of the information through the structured query language (SQL - Structured Query Language). These routines are stored in the system, which allows their reuse. This facilitates the process of updating the information when required.

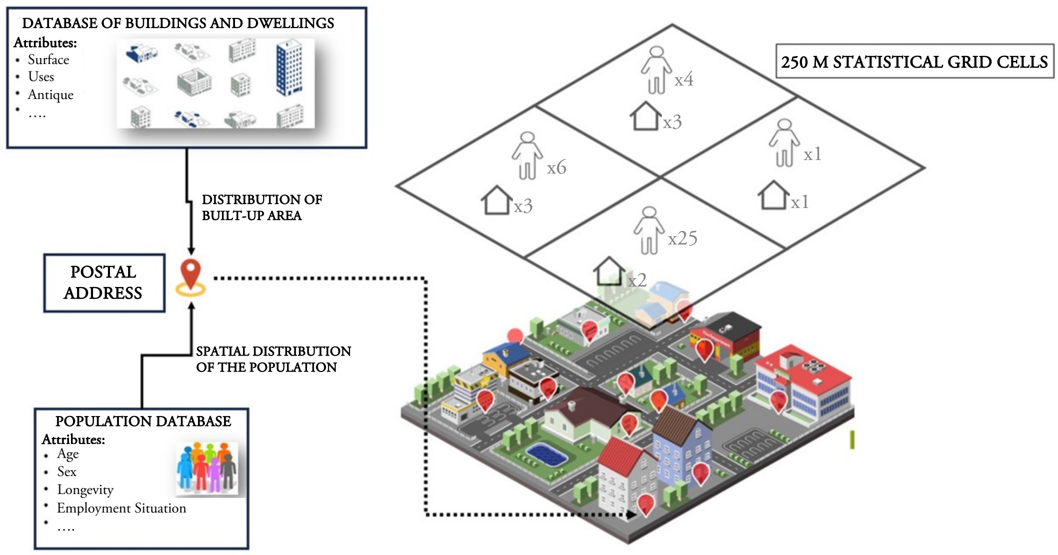
### 3.1. Spatial Distribution of the Andalusian population, 2013–2020

The objective of this task was to represent the Andalusian population in a territorial disaggregation level with reduced dimensions and with a homogeneous unit of observation. For this purpose, a regular grid formed by square cells with 250-m sides was used in which the Andalusian population data were retrieved from the Andalusian Population Longitudinal Database (*Base de Datos Longitudinal de la Población de Andalucía* – BDLPA) (Viciana-Fernández *et al.*, 2010). A regular grid was generated following the indications derived from experiments conducted by the EFGS Geostat project (EFGS, 2012, 2013 and 2017).

Population geocoded data used in the experiment was geocoded to building entrances, since x–y coordinates for building entrances are available in a standard reference system for Andalusia. Geocoded datapoints were added to each spatially corresponding cell (Figure 1). This approach made it possible to preserve statistical confidentiality and facilitate the disclosure and cartographic representation of information, as well as the possibilities of spatial analysis.

The data on population were geocoded by assigning geographic coordinates from the Unified Digital Street Map of Andalusia (*Callejero Digital de Andalucía Unificado* – CDAU) or the Building Census to BDLPA addresses, through data linkage (Christen and Churches, 2005; Christen, 2012; IECA, 2018). The process followed to link both datasets was complex and consisted of different phases (IECA, 2022) for georeferencing all BDLPA addresses, assigning to each of them the coordinates of the building entrance of the dwelling registered in CDAU or the Building Census. An X and Y coordinate of the alphanumeric database of CDAU building entrances (house numbers) and street names were assigned to the postal addresses of the dataset to be geocoded, using the postal addresses of both as the junction point between both datasets. Once a layer of points representing the building entrances with the number of inhabitants and their sociodemographic characteristics was generated, these geocoded data were added to each cell with 250-m sides.

**Figure 1.**
**Methodology**




The information represented in these maps refers to January 1 of the corresponding year and includes demographic (total population by sex, nationality, or age group) and labor (total employment by sex or employment status retrieved from Social Security records; and total number of job seekers, by sex or registered unemployment) data, as well as data on contributory pensions (retirees by sex; type; and by income from retirement, widowhood, disability, or other types of pensions).

## 3.2. Longitudinal Statistics of Survival and Longevity in Andalusia, 2002–2016

Another interesting experiment using a statistical grid in the Andalusian context was developed by longitudinally exploring BDLPA. Integrating statistical data on events with the different population census rounds and georeferencing the population data facilitated the development of longitudinal research in different areas with a wide range of personal, family, and environmental characteristics and with an infra-municipal territorial detail.

In this line of research, results on Standardized Mortality Ratio (SMR) data for 250m side cells have been published[1]. SRM indicator is not affected by the population structure, thus making it possible to compare mortality rates between populations with very different structures. SMR is calculated by estimating the number of cases (deaths) that would occur in a specific area, with a known structure, if it were subjected to the intensities determined by the standard rates. Thus, a different result can be obtained, which is termed “expected cases”. The ratio between the number of actually observed and expected deaths is the SMR indicator for a territory or area. Reducing the territorial scope of analysis from a census tract to a regular cell means that the observations in the unit of interest may not suffice to estimate the SMR

[1] https://www.juntadeandalucia.es/institutodeestadisticaycartografia/dega/estadisticas-longitudinales-de-supervivencia-y-longevidad-en-andalucia

indicator and its significance. For this reason, mortality indicators are also estimated in a small area, thereby assessing the Smoothed Standardized Mortality Ratio (SSMR).

SSMR was calculated using the risk exposure times in the 2002–2016 period at various levels of detail, thus showing the degree of mortality by cell and associating the data with population parameters (unemployment and educational level, among others) retrieved from the various administrative and census records.

## 3.3. Distribution of built-up area (250 m × 250 m cells), 2020

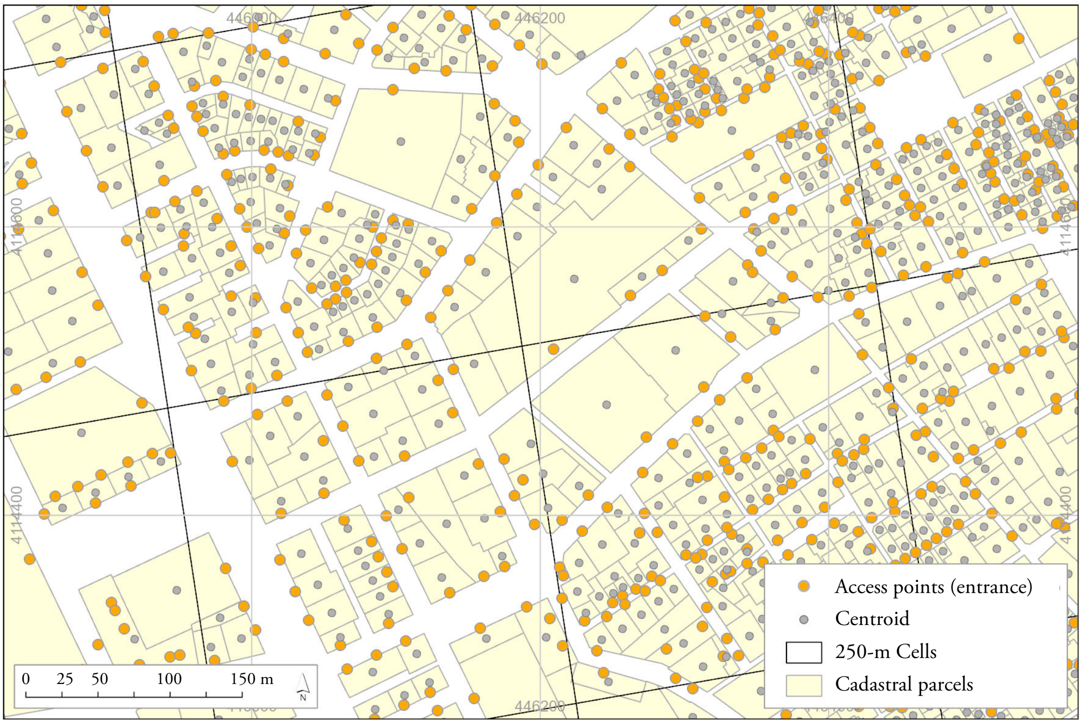
The objective of this activity was to provide information on the distribution of built-up areas in the territory and their characteristics. The distribution of buildings, dwellings, and non-residential premises in Andalusia were represented on a map, seeking a broad territorial disaggregation and spatial homogeneity of data retrieved from the Real Estate Cadastre (*Catastro Inmobiliario* – CI). In addition, their spatial relationship with all the information that can be integrated in the same statistical grid of demographic data was studied.

CI is a well-established, complete, and comprehensive administrative registry from which rich and illustrative information on the urban characteristics of the territory can be extracted from various points of view. Despite being prepared for fiscal, not statistical, purposes, this information is comprehensive and accurate in both its spatial and thematic components and is therefore a highly valuable source of statistical data with a very wide potential (*Real Decreto Legislativo* (RDL) [Royal Legislative Decree] 1/2004, March 5, *Boletín Oficial del Estado* (BOE) [government gazette] 58; Villarín, 2015; Pérez-Alcántara *et al.,* 2016, 2017; Llausàs *et al.,* 2018; Ojeda and Paneque, 2018).

During the project of characterization and distribution of data on the built-up area of Andalusia in regular cells, two key decisions were made. The first was related to the spatial unit of observation and its integration into the corresponding cell in each case. In Spain, cadastral data are basically organized using the cadastral parcel as a spatial reference. When working with both real (the parcel) and virtual (the cell) spatial features, a border space may belong to two cells. Thus, to facilitate the integration of cadastral information into cells, geometric point features were generated to gather all data on real estate located in that spatial entity. A layer of points has been generated, containing an access point for each real estate property included in the Cadastral file. The preferred identification method has been the identification of a point according to the real state entrance postal address. Although the cadastral centroid of the parcel can be used as a point feature, in this project, a layer of point features located in the space overlapping the location of the buildings was generated instead, thereby increasing the spatial accuracy in the location of the built elements (Figure 2). For this reason, a higher accuracy was also achieved in the statistical analysis of the thematic characteristics of the data and in their assignment to the cells of the statistical grid.

The second key decision was the definition of the elements to be identified from the cadastral data. These elements were buildings, dwellings, and non-residential premises, as well as their specific characteristics. In Spain, cadastral data are organized into the following three levels: parcel, real estate, and constructions. Cadastral data do not include buildings, dwellings, or non-residential premises, but the cadaster is nevertheless a source of data for identifying these features. Knowing the distribution and structure of the built-up area makes it possible to estimate the behavior of the population in terms of land use.

**FIGURE 2.**
**Location of the built elements in Granada**




## 4. RESULTS

The Institute of Statistics and Cartography of Andalusia (*Instituto de Estadística y Cartografía de Andalucía* – IECA) prepared its first population distribution map in 250-m cells in 2013. This map was a major qualitative advance. Since then, a map has been drawn with the most updated population distribution data every year by performing a georeferencing process combining a massive number of data using postal addresses as link information. In this process, the order of priority was set by stages. The first stage consisted of geocoding to an exact building entrance, continuing with the nearby building entrance and the center of the street (with location corrections). The main sources of data for locating the building entrance were firstly the CDAU and secondly the Population and Housing Census (*Censo de Población y Viviendas*). The eight editions that have been produced so far make it possible to assess the population evolution and the process of creating these layers. Thus, in 2013, a total of 8.3 million people were located to their building entrance, occupying 48,187 cells of a total of 1.42 million that covered 87,000 km$^2$ of Andalusia. By 2020, 53,243 cells were occupied. This difference of more than 5,000 cells resulted not only from changes in the population distribution but also and primarily from the processes of cleaning up the location of the data. This process of identifying the spatial location of the population in the building entrance where they are living is becoming increasingly more accurate thanks to the gradual expansion of building entrance points from the different sources that are used for this purpose and to improvements in the processes of linking demographic data to those of building entrance sources. The number of inhabitants in Andalusia was very similar in the eight reference years (approximately 8.4 million people). The number of building entrance points with a resident population totaled 1.56 million in 2020 and 1.42 million in 2013. Even more significant are the figures for direct georeferencing of building entrance, which increased by almost one percentage point from 94.98 to 95.82% between 2014 and 2020. The allocation to the exact building entrance increased by 2.3 percentage points, whereas the allocation to the exact CDAU building entrance increased by just over 11 percentage points (72.7–83.8%).

Table 1.
Population data assignment to building entrance and cells

| Year | Number of cells | Number of postal addresses | Number of building entrance | Geolocated population | % direct georeferencing | | | % indirect assignment |
|---|---|---|---|---|---|---|---|---|
| | | | | | Total | Exact building entrance | Exact CDAU building entrance | |
| 2013 | 48.187 | 1.554.321 | 1.421.015 | 100,0 | 93,30 | | | 6,70 |
| 2014 | 50.602 | 1.682.121 | 1.522.435 | 100,0 | 94,98 | 92,12 | 72,70 | 5,02 |
| 2015 | 50.314 | 1.685.554 | 1.523.095 | 100,0 | 94,86 | 91,89 | 72,61 | 5,14 |
| 2016 | 50.818 | 1.691.981 | 1.514.291 | 100,0 | 95,46 | 92,12 | 73,36 | 4,54 |
| 2017 | 50.758 | 1.679.346 | 1.525.520 | 100,0 | 95,40 | 92,20 | 74,85 | 4,60 |
| 2018 | 50.747 | 1.679.961 | 1.534.642 | 100,0 | 95,88 | 93,05 | 81,91 | 4,12 |
| 2019 | 52.599 | 1.686.224 | 1.549.755 | 100,0 | 96,08 | 93,74 | 83,26 | 3,92 |
| 2020 | 53.243 | 1.690.676 | 1.559.834 | 100,0 | 95,82 | 94,46 | 83,81 | 4,18 |

The 2013 data are based on a direct and indirect allocation method, different from that used for the data from the other years. CDAU, Unified Digital Street Map of Andalusia (*Callejero Digital de Andalucía Unificado*)

The percentage of occupied cells per resident population ranged from 3.50–3.76% of all cells in Andalusia depending on the year. The referencing of the population to the building entrances that matched their place of residence and subsequent aggregation into cells highlighted the different distributions of the population in the territory. Thus, approximately 40% of the inhabited cells were occupied by 10 or fewer inhabitants, although 0.5–1% of the population lived in this type of cell. This was in contrast to a more marked characteristic of Andalusia, the strong concentration of the population in urban centers with high demographic density, both in traditional Andalusian settlements and more recently, in densely populated urban centers. More than 60% of the population lived in cells ranging from 100 to 1,000 inhabitants, and almost 30% of the population lived in cells with a number of inhabitants ranging from 1,000–2,500. Because the cells were homogenous in terms of shape and size, the data could be directly compared spatially and temporally because they were not affected by the variability in the size of the units of observation.

The statistical grid was established as one of the European Union territorial typologies in the TERCET[2] regulation, together with the Nomenclature of Territorial Units for Statistics (NUTS) and Local Administrative Units (LAU). The population distribution by nationality, age group, and any information considered interesting, can also be determined, thus highlighting the potential of these analyses. IECA produces and reports most of these data[3]. Figure 3 shows the detail of the population of 60 years of age or older, living alone or in the company of people 60 years of age or older, as well as the percentage of people in that age group with respect to the total population. These data highlight the distribution pattern and the need for specific public policies to meet the needs of this population group. By now, the usefulness of using small and regular units is clear. The information presented in Figure 3 using 250-m cells as the unit of observation is presented in Figure 4 using the census tract. The homogeneity of each cell facilitates the spatial analysis, highlighting territorial patterns. As a heterogeneous spatial unit, the census tract complicates these analysis tasks.

The information that can be consulted and analyzed in these population distribution maps has been expanding across editions. Data on the number of pensions and on the amounts received for contributory pensions has been provided since 2015. Data on the population seeking employment, disaggregated by gender, has been reported since 2017, and information on the population permanence in the municipality of residence has been added since 2018.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32017R2391&from=ES
[3] https://www.juntadeandalucia.es/institutodeestadisticaycartografia/dega/distribucion-espacial-de-la-poblacion-en-andalucia

FIGURE 3.
**Population 60 years of age or older, living alone or in the company of people 60 years of age or older in 2020. Seville**

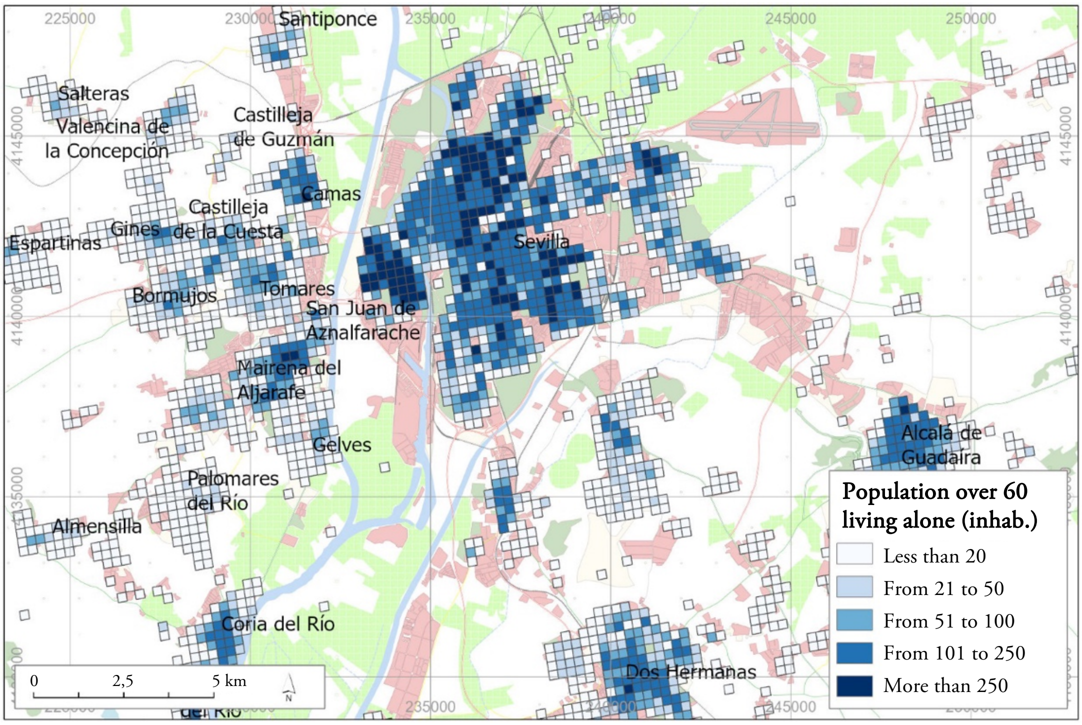
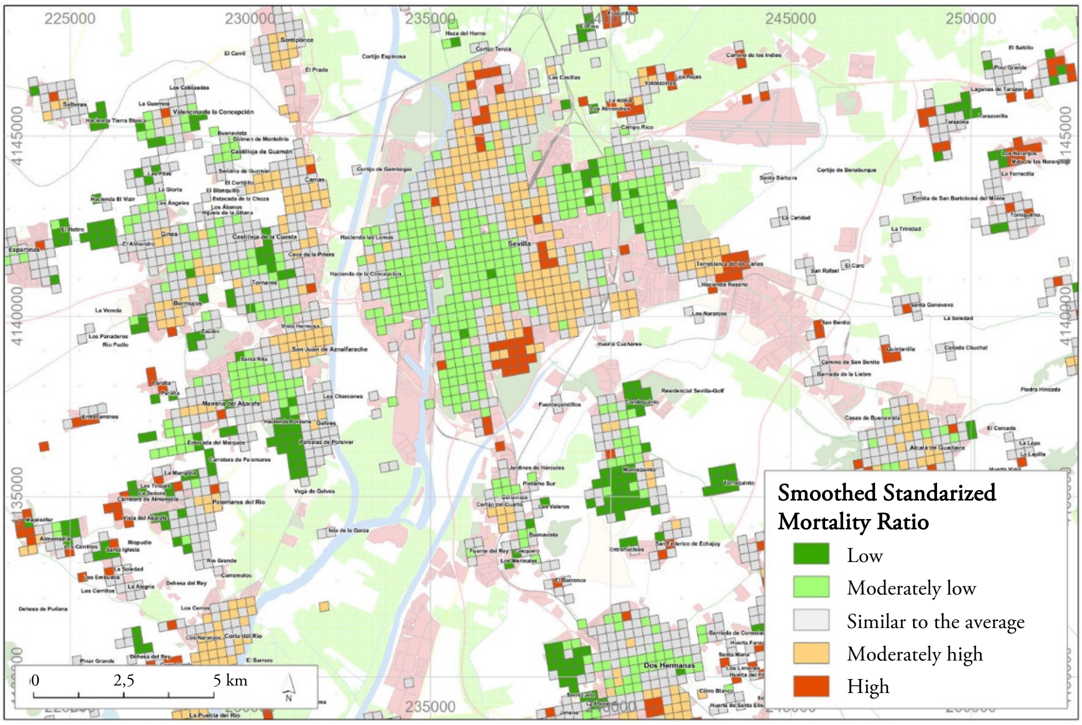



FIGURE 4.
**Population 60 years of age or older, living alone or in the company of people 60 years of age or older in 2020 (census tracts). Seville**

This analysis is also enriched by including data on longitudinal survival and longevity statistics. These data, combined with the previous information, reveal the existing relationships between them. In general, cells with a moderately low or low SSMR (Figure 5) are located in areas with a high socioeconomic level, whereas those with high or moderately high SSMR correspond to areas of a more disadvantaged socioeconomic level.

**FIGURE 5.**
**Smoothed Standardized Mortality Ratio (SSMR) in Seville**



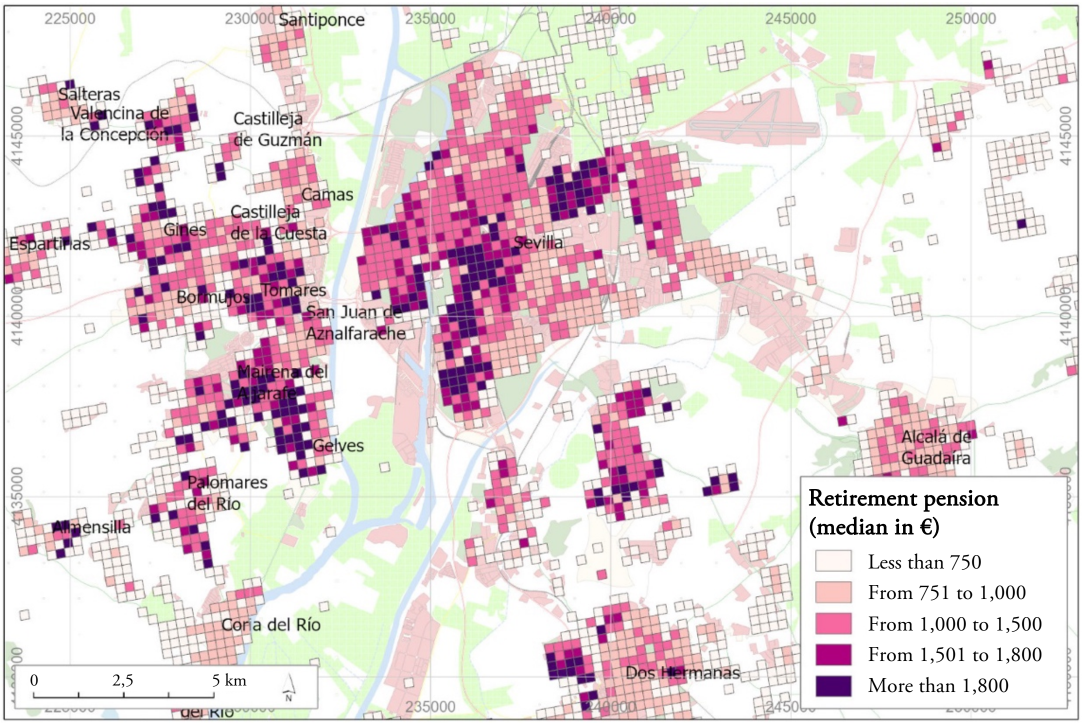

This correlation was verified when comparing these SSMR data with the data on unemployment percentages or average pension income contained in each cell (Escudero *et al.*, 2023). The results showed that cells with low or moderately low mortality matched those where retirement pensions ranged from €1,800–€2,000 on average, in contrast to those in areas with high or moderately high mortality, where the retirement pensions ranged from €750–€1,000 (Figure 6).

Data on built-up areas can also be included in the analysis, which makes it possible to know, for example, the typology or the average dimensions of dwellings of the population with above- or below-average mortality. The data showed that population with low mortality rates tended to live in dwellings found in cells of densely populated urban expansion zones of predominantly residential use, in isolated single-family dwellings, and in large parcels. Medium and large houses prevailed in the cells where swimming pools and private gardens were commonly found. Similarly, other cells with high mortality matched the locations where the housing quality was lower than in the previous cases. This does not indicate that the residence directly determines the mortality ratio but does indicate that some socioeconomic characteristics are more frequent in populations with moderately low mortality.

Within the cadastral information, all real estate was characterized for the valuation of each property. This assessment generated a zoning with strikingly marked patterns, which also matched the zones generated from SSMR data.

The data analyzed in this article and its form of aggregation in regular cells open up opportunities to analyze many other variables related to health, employment, and quality of life in general within the different clusters that can be established in the territory, as well as the spatial patterns that explain such clusters. In recent years, maps of the spatial distribution of deaths by cause at a municipal scale have been drawn, highlighting deaths caused by some types of cancer, while presenting data at the municipal level. At these scales, it is difficult to explain all the reasons for the observed territorial patterns, but in more disaggregated spatial units and with related thematic content, the causes of specific spatial patterns and their relationships with some socioeconomic parameters can be addressed.

**FIGURE 6.**
**Retirement pension income in Seville**




Of the cells that cover the Andalusian territory, 216,154 included at least one building, accounting for 15.3% of the total number of cells, in contrast to 3.7% cells by population. This difference identifies the territorial segmentation of building uses and shows that the population primarily lives in defined areas of the territory. Under these conditions, the distribution of the population by place of residence must be considered, for example, by comparing the map at night and day, or seasonally, to locate the population in other places for different reasons (work, studying, and vacation, among others).

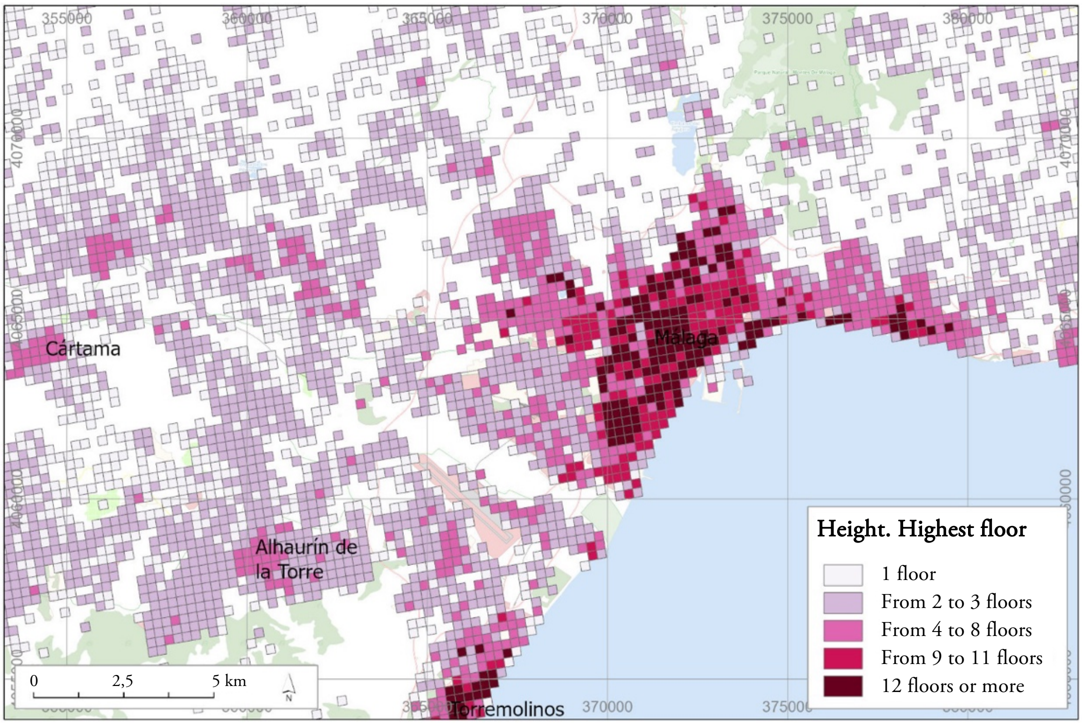
Within the cells with at least one building, the density ranged widely, and a high number of cells had a low density of buildings. In addition, 181,018 cells had fewer than 10 buildings, accounting for 83.7% of the total number of cells with buildings. Others had a high number of buildings (70 cells had more than 400 buildings) and largely corresponded to areas with a high density of multi-family dwellings or, to a lesser extent, single-family dwellings in condominiums, in settlements with a traditional structure, or densely populated urban centers. In these cases, the high density reflected the number of buildings, but not the built-up area, since the latter was found in cells with other types of buildings with industrial, port, or military uses. The information that could be extracted refers to specific characteristics of the buildings, not only related to their use but also to their main characteristics.

In the construction category, the prevailing presence of buildings in each cell was classified into high, medium, or low, based on criteria established by the Directorate-General for the Cadastre (*Dirección General del Catastro* – DGC) and reflected the territorial pattern of this variable. This category refers to the materials, techniques, and finishes that determine the value of the construction within the cadastral valuation.

The age of the buildings is a variable that makes it possible to analyze the territory and monitor how the built-up area grows, the evolution of cities, and land-use patterns. The year of construction also reflects other less visible aspects, such as those derived from adaptations to current regulations. The adaptation of buildings to guidelines on energy efficiency offers an indirect approach to their quality linked to their construction characteristics and to their spatial distribution. Energy efficiency is an equally relevant aspect in achieving the Sustainable Development Goals, where Goal 7 indicates double the global rate of improvement in energy efficiency by 2030.

Another variable that characterized the built-up area was the height of the buildings (Figure 7), expressed as square meters of built-up area on a given plot of land. Striking patterns were observed with low-rise buildings, in terms of the number of floors in residential buildings in areas of traditional settlements; single-family dwellings; or buildings with specific uses, such as industrial, sports, cultural, entertainment, or religious venues, whereas buildings with a high number of floors were found in expanding areas with residential buildings, such as multi-family dwellings, offices, or leisure and hospitality buildings.

**FIGURE 7.**
**Height of buildings in Malaga**

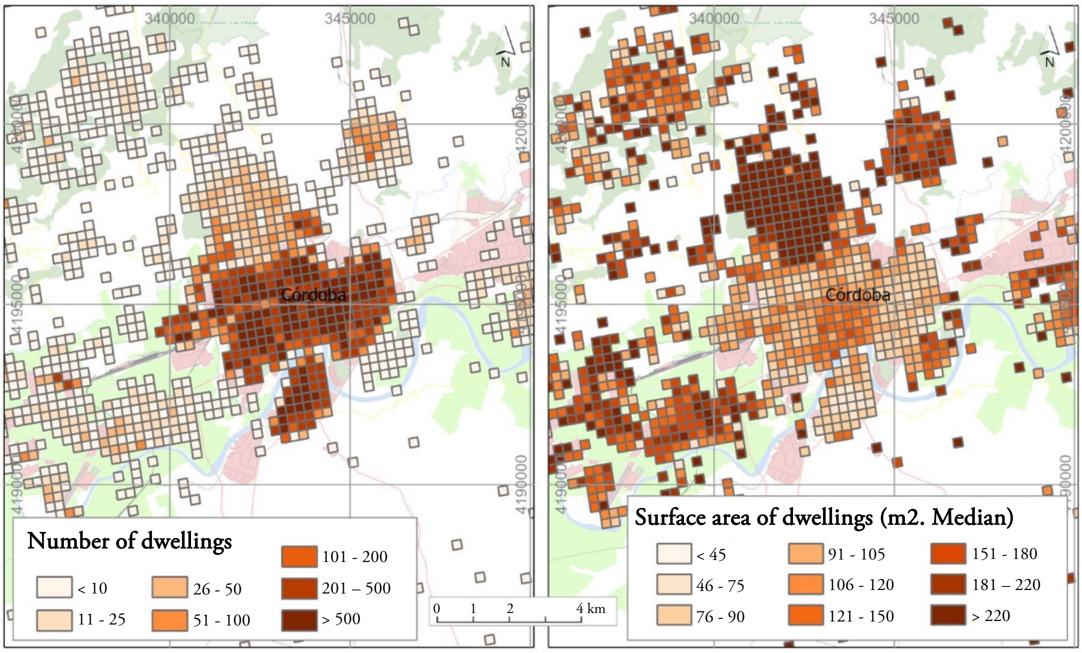



Of the more than 216,000 cells with at least one building, 141,694 had at least one dwelling, accounting for 10.0% of all cells that cover the Andalusian territory. The housing density per cell also varied widely. A high number of cells had a low housing density; more specifically, 109,423 cells had fewer than 10 dwellings (77.2% of the total number of cells with dwellings), in contrast to densely built cells (1,669 cells with more than 500 dwellings). Moreover, just over 60,000 cells had only one dwelling, a fact that is indicative of the existence of some dispersion of dwellings in a few areas of the Andalusian territory, in contrast to a strong concentration in some urban areas. The latter is a typical settlement in Andalusia.

In the analysis based on information of the built-up area and specifically of the residential area, referencing the information of regular cells with small dimensions was also highly useful. Thus, more than half of the homes in Andalusia had a built-up area ≤100 m², which ranged as a function of the typology of the dwellings and the areas where these dwellings were located. Figure 8 shows a highly frequent pattern, such as that of the urban center of an Andalusian city, in this case Córdoba, where the housing distribution varied with its own characteristics. A significant number of multi-family dwellings were concentrated in the central urban area, in contrast to suburban areas, with a greater presence of single-family dwellings and significantly larger dwellings than those observed in the central area of Córdoba.

Relationships between the different phenomena under study can be identified by integrating information from different sources into homogeneous and small units of observation. The long weeks of lockdown decreed in Andalusia and Spain in the spring of 2020 due to the coronavirus disease 2019 (COVID-19)-pandemic highlighted the importance of having information on the characteristics of residences to assess the circumstances and conditions under which the population lived during this period. The availability of these data on dwellings and population in an identical zonal system facilitates the study of the profile and characteristics of dwellings built in inhabited areas.

**Figure 8.**
**Total number and size of dwellings in Cordoba**




## 5. Conclusions

Processing large volumes of spatial data and linking records are essential steps in these projects. Accordingly, technological developments in recent decades have increased these capabilities.

Although both the sources of information and the georeferencing processes have been perfected in successive editions, the percentage of non-georeferenced addresses has remained relatively stable at approximately 4.5% since 2016. Analyzing the casuistry of these non-georeferenced addresses, inquiring whether they are concentrated in specific areas of the territory, whether some addresses are repeated or, conversely, renewed in each edition and correspond to new addresses, and assessing the effect of the indirect location of these addresses are lines of improvement that require a specific analysis.

Regarding the location of the cadastral information, the most relevant decision is to generate the specific cadastral feature in the accurate place where the real estate is located within the cadastral parcel, thus reducing the spatial distortions that occur when locating the cadastral information in the centroid of the parcels. Among these decisions, the location of the entity was also shown to be key, coinciding with the place of access to the buildings from the public space. The location criteria are unified and accurately defined so that they can be refined in future processes.

A regular grid, in shape and size, was used in the studies analyzed in this article, and proved to be highly useful for the tasks of analysis and synthesis of information and decisively helped to trace the patterns of spatial behavior of the variables. Such a grid is particularly useful, among other things, in planning public services. This grid makes it possible to individualize the territory, to integrate information in a simple way, to dimensionalize the information integrated in each unit, and facilitate comparison between units and between areas since this comparability is not distorted by the dimensions or by the shape of the unit of analysis. As such, this grid is an advance in solving problems raised by MAUP.

These aspects were clearly observed in the examples analyzed in section 3, which included some samples of data from significant examples within the territory with diverse variables. The homogeneity of all cells facilitated their comparison, in contrast to the use of administrative units, thus making it is easier to determine, after performing the pertinent analysis, the type of cell in which each of them was located, based on the population density and its socioeconomic characteristics, as well as that of the urban variables. The operations of analysis were not altered by the heterogeneity of the territorial units.

Regarding the size of the unit, the same approach as that used for the map of Europe with 1-km cells was followed, albeit reducing the size of the cell to 250-m. These cell dimensions were highly suitable for achieving the objectives set out in these studies because, on the one hand, a very broad level of disaggregation was reached and, on the other hand, features with a considerably valuable level of spatial homogeneity were generated.

However, in order to develop it, it is necessary to have georeferenced information at a high level of disaggregation. There are still significant difficulties in carrying out this type of analysis, since there is still little disaggregated information that can be used. Thus, projects such as these are intended to demonstrate the potential of analyses of this type and, together with the results of other works that have advanced along the same lines, to promote that in the future it will be considered increasingly necessary to have highly disaggregated and correctly georeferenced information. This information should be increasingly accessible for the analysis of the territory from different thematic perspectives, which will improve the analyses developed with information in administrative units.

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Articles

# The waiting times distribution of public hospitals using a GAMLSS approach: the case of Andalusia (Spain)

*Angela Caro*, Julia De Haro-García***

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## Abstract:

Patients' waiting times are caused by the imbalance between the available supply and the existing demand in the health sector. Exceeding maximum waiting times may worsen diseases and entail additional costs to public health systems. This paper studies the theoretical probability distribution that best fits the average waiting times for non-urgent surgeries and first outpatient consultations for Spanish public hospitals in the region of Andalusia. For doing this we apply Generalized Additive Models for Location, Scale and Shape, which cover a wide range of probability distributions. We propose the final selected models as a tool to be considered by health authorities for a better management of waiting times/lists.

**Keywords:** Model selection; GAIC; GAMLSS; waiting lists; waiting times.
**JEL Classification:** C14; I18; O18; R10.

## La distribución de los tiempos de espera de los hospitales públicos usando un enfoque GAMLSS: el caso de Andalucía (España)

## Resumen:

Los tiempos de espera de los pacientes se deben al desequilibrio entre la oferta disponible y la demanda existente en el sector sanitario. Superar los tiempos máximos de espera puede empeorar las enfermedades y suponer costes adicionales para los sistemas de salud públicos. Este artículo estudia la distribución de probabilidad teórica que mejor se ajusta a los tiempos medios de espera para cirugías no urgentes y primeras consultas ambulatorias en los hospitales públicos españoles de la región de Andalucía. Para ello aplicamos Modelos Aditivos Generalizados de Ubicación, Escala y Forma, que cubren una amplia gama de distribuciones de probabilidad. Proponemos los modelos finales seleccionados como una herramienta a ser considerada por las autoridades sanitarias para una mejor gestión de los tiempos/listas de espera.

**Palabras clave:** Selección de modelo; GAIC; GAMLSS; listas de espera; tiempos de espera.
**Clasificación JEL:** C14; I18; O18; R10.

## 1. Introduction

The problem of waiting lists is a worldwide issue in public health systems. Countries must deal with the main two challenges that waiting list encompasses: the total number of people on the waiting list and the time of healthcare delay. Efficient management of these lists by national health systems will make their

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users more satisfied, while achieving less damage to their health, since sometimes long waiting times can aggravate illnesses and even lead to death.

As evidence of the relevance of this topic, the OECD has also put the focus on waiting times, publishing reports, see for example OECD (2020), and establishing a database, Waiting Times for Health Services (https://data.oecd.org/health.htm). The information published on waiting times corresponds to selected elective (non-emergency) surgeries, such as knee and hip replacement, among others. The database includes waiting times from specialist assessment to treatment and waiting times of patients on the list. Nevertheless, it is important to note that the data is not homogeneous given that the methodology of computation differs in most countries.

There exists a considerable body of literature on waiting times. Here we summarize the contributions analyzing waiting times according to different national health systems. The present work focuses on the Spanish National Health System (SNHS) which has been considered in recent years by Abásolo et al. (2014a, 2014b), Díaz and Iglesias-Gómez (2013), Granado and Vega (2014), and López-Valcarcel and Barber (2017), between others. Abásolo et al. (2014a), using aggregate data of all the 17 Spanish regions and Ceuta and Melilla, study patients' socioeconomic status and identify the existence of a high degree of asymmetry in the distribution of waiting times, and Abásolo et al. (2014b) estimate that the non-urgent surgery total waiting time distribution is markedly positive asymmetric when analyzing three surgical procedures in the Spanish regions of Galicia and Murcia. Díaz and Iglesias-Gómez (2013) and Granado and Vega (2014) study the productivity and efficiency of the SNHS by regions through DEA (Data Envelopment Analysis) models. Both studies consider data covering all Spanish regions. The first includes in the model the satisfaction perceived in hospitals and specialized care. The second proposes using the DEA efficiency analysis as a hospital benchmarking tool. The results show important differences between regional health systems. López-Valcarcel and Barber (2017) reviews economic and medical research publications to analyze the effects of the actions taken in the national public health system after the economic and financial crisis of 2008. Inequalities in waiting lists due to socioeconomic status have been discussed by Abásolo et al. (2014a) in the case of Spain, Monstad et al. (2014) in Norway, and Simonsen et al. (2020) in Denmark, among others. The latest contributions analyzing the SNHS apply econometric models and show that there is growing evidence that among patients with similar levels of need, waiting times often differ according to socioeconomic status, see Garcia-Corchero and Jiménez (2022), and Bosque-Mercader et al. (2023). Related to the Portuguese National Health System, Madeira et al. (2021) analyzes the relationship between operational and healthcare professional costs and waiting lists, and Cima and Almeida (2022) estimates survival models introducing cancellation rates as censored data. Finally, in the case of the English National Health Service, Dawson et al. (2004) studies whether patient choice is an effective mechanism to reduce waiting times, Dimakou et al. (2015) finds important differences on the 'scale' and on the 'shape' of admission rates, and Nikolova et al. (2016) analyzes the impact of waiting times on the effectiveness of treatment from different surgeries.

Given the role that hospitals play in the phenomenon of waiting lists and, specifically, in waiting times, we will focus on modelling waiting times at the hospital level for the Spanish public health system, specifically for its most populated region: Andalusia. The analysis of the behavior of the response variable is crucial to carry out an econometric study, since, for example, linear models require the normality assumption. Therefore, the main goals are: first, to establish a correct functional form of the waiting time variable; and second to have a forecasting tool based on the waiting times probabilities that can be estimated with the final selected distribution. The analysis will be done at two levels: for non-urgent surgery waiting times and for outpatient consultations waiting times (first visit), for the latest available data, June 2022. We will analize the entire set of Andalusian public hospitals, and four concerted hospitals which have established some type of agreement with the Andalusian Health System (AHS, from now on). Concerted hospitals are approved and integrated into the care network of the AHS. Throughout the text, we refer to all hospitals under study as public hospitals.

The methodology and the study carried out here is exportable to other Spanish regions as well as to other countries. Priority is given to the task of finding an optimal theoretical model that fits the empirical distribution of the data. We use the GAMLSS methodology (Generalized additive models for location, scale and shape) proposed by Rigby and Stasinopoulos (2001, 2005), and goodness-of-fit instruments, both graphical, Cullen and Frey (1999) graph, and through information criteria such as GAIC (Generalized Akaike information criterion), Akaike (1983). The GAMLSS is an approach that substantially improves generalized linear models and generalized additive models and is applicable both to a single variable and to an econometric model. In the latter case, a prior study of the dependent variable to be analyzed is required, an issue that goes unnoticed in most econometric studies. In our case, for each variable of average waiting time, surgery and outpatient consultations, we estimate the probability that an Andalusian hospital exceeds a certain average waiting time. Based on this information, we estimate the number of hospitals and the number of patients on the waiting list who exceed these times. Given the characteristics of our variables, asymmetric and leptokurtic, the GAMLSS methodology is highly recommended.

Finding a suitable model that fits waiting times will help health institutions in the design of strategies, implementing better management resources and making them more efficient.

The paper is structured as follows: Section 2 describes the dataset and the methodology to fit the optimal theoretical density function to the observed data. Section 3 introduces the Spanish national health system features, as a whole and by regions. Section 4 presents a descriptive analysis of waiting times and waiting lists in Andalusian public hospitals, and the empirical analysis of waiting times is performed in Section 5. Finally, Section 6 presents some conclusions and insights for health authorities and policy makers.

## 2. Methodology

Previous to establish a correct functional form of the waiting time variable for the entire set of Andalusian public hospitals, using the Cullen and Frey graph and the GAMLSS methodology, we provide descriptive analyses of this variable at the regional level in Spain and for Andalusian hospitals.

### 2.1. Data

We begin the study on waiting times at the regional level with Andalusia, which publishes aggregate information in greater detail than in the national case. Specifically, data on average waiting times for the entire region is available for each province and by hospitals, for non-urgent surgeries[1] and for outpatient consultations, from June 2019 to June 2022[2]. Finding this information by public hospitals has not been possible for other regions, so the study in subsequent sections has been restricted to Andalusia, which is the second largest region in Spain and the one with the largest population.

According to the AHS, a surgery waiting list is defined as patients registered in the Surgical Demand Registry, pending a non-urgent intervention. In this list we can find the following types of patients:

- Patients on the surgical waiting list with a guarantee: Patients with a guaranteed response time of 90, 120 or 180 days and whose registration maintains the term guarantee of response[3]. Also included in this list are patients pending after the deadline (with guaranteed rights who have exceeded the corresponding maximum response period) and those temporarily non-programmable (TNP) for clinical reasons or at the request of the patient.
- Patients on the surgical waiting list without guarantee: Patients not included in the guaranteed sections or who have lost the response time guarantee. This list also includes patients with a waiting period of more than 365 days and TNP.

[1] Urgent surgeries, organ transplants, as well as those produced in catastrophic situations are excluded.
[2] Data source: https://www.sspa.juntadeandalucia.es/servicioandaluzdesalud/el-sas
[3] According to Royal Decree 605/2003, at a national level, the following distribution of pending patients is established by waiting period: 0-90 days, 91-180 days, 181-365 days, greater than 365 days. According to Royal Decree 1039/2011, it is established that the guarantee periods are less than 180 days for certain surgical interventions. The regions may shorten said maximum terms depending on the type of intervention to be carried out.

**Average waiting time for non-urgent surgeries** is understood to be the average time, expressed in days, that patients pending an intervention have been waiting, from the date of entry in the Surgical Demand Registry until the final date of the study period (cut-off date, June 30, or December 31). These average delay data differ slightly from those published by the SNHS since they compute the waiting times corresponding to pending patients on structural waiting, that is, without including those TNP. The data published by the AHS does include the latter, who usually constitute a very low percentage of the total number of pending patients, 2.9% in June 2022.

In the same sense, there is a waiting list for outpatient consultations, referring to first consultations with specialists, guaranteeing a maximum response time of 60 days. The response guarantee system ensures citizens maximum waiting times, since if the response deadlines established in the regulations are not met, they have the right to go to a private center and the AHS will charge of the expenses incurred. In this area and according to the AHS, we highlight the following concepts:

- Waiting list for external consultations: Patients registered in the Register of External Consultations, pending to be seen by a medical specialist in hospital care.
- First consultations: Requests for outpatient hospital consultations made by a primary care doctor (first consultations from primary care) or by another hospital care doctor (interconsultations).

**Average waiting time for a first specialized care consultation** is understood to be the average, in days, of the time that patients pending a first consultation have been waiting, since the date of entry in the Register of External Consultations until the end date of the study period (cut-off date)[4].

We consider in this study the AHS data for each hospital on the average surgery waiting time (*Surgery*, from now on) and on the average outpatient consultation waiting time (*Outpatient consultations*, from now on), for data up to June 2022. The former includes both the average waiting times corresponding to patients pending scheduled surgical procedures, structural waiting, as well as the temporarily unscheduled. The latter includes both waiting times for consultations from primary care as well as hospital interconsultations[5].

## 2.2. Cullen and Frey graph

Cullen and Frey (1999) develop a graph where the asymmetry and kurtosis coefficients are combined for a group of probability functions. The probability functions are the most used for models with one or two parameters. For continuous random variable, such are our variables, it includes the normal, uniform, exponential and logistic models, in which a single point shows the situation of each model based on the combination of asymmetry or kurtosis coefficients. The Gamma and Log-normal models are represented by dashed lines, and the Weibull model will be close to both models. According to Delignette-Muller and Dutang (2015), to provide greater robustness, skewness and kurtosis are evaluated on bootstrap samples.

According to Cullen and Frey (1999) we also consider the following classical goodness-of-fit plots:

- A density plot representing the density function of the fitted distributions along with the histogram of the empirical distribution.
- A CDF (Cumulative Distribution Function) plot of both the empirical distribution and the fitted distributions.

[4] In this regard, it should be noted that there are other indicators such as the average waiting time for patients who have already undergone surgery, as well as the average waiting time to be seen in a first consultation, which are not provided on the AHS website for each hospital.

[5] The formula for calculating Surgery and Outpatient consultation for each hospital is: the sum of the waiting days of patients pending a surgical intervention/first consultation, divided by the total number of patients pending an intervention/first consultation, on the date of cut, respectively.

- A Q-Q plot representing the empirical quantiles (y-axis) against the theoretical quantiles (x-axis).
- A P-P plot representing the empirical distribution function evaluated at each data point (y-axis) against the fitted distribution functions (x-axis).

Next subsection presents the GAMLSS methodology which is not reduced to the field of biparametric distributions traditionally used in the literature, but rather that these models will compete with models with three and four parameters.

## 2.3. The GAMLSS framework

Generalized additive models for location, scale, and shape (GAMLSS) were introduced by Rigby and Stasinopoulos (2001, 2005) as a way of overcoming some of the limitations associated with the popular generalized linear models, GLM, and generalized additive models, GAM, see Nelder and Wedderburn (1972) and Hastie and Tibshirani (1990), respectively.

GAMLSS models are semi-parametric regression models. First, they are parametric, in the sense that they require a parametric distribution assumption for the response variable. Second, they are semi-parametric, in the sense that the modeling of the parameters of the distribution may involve using non-parametric functions. GAMLSS can model many distributions, Normal, asymmetric, and with heteroscedasticity, between others. For this, the response variable, $y$, can be adjusted through a parametric distribution of up to four parameters, $f(y_i|\mu_i, \sigma_i, \nu_i, \tau_i)$, where μ, σ, ν and τ, represent the location, scale, skewness, and kurtosis shape parameters, respectively. For the estimation of the parameters, Rigby and Stasinopoulos (2005) introduced two basic algorithms: CG (Cole and Green) and RS (Rigby and Stasinopoulos) which maximize the logarithm of the likelihood function.

The GAMLSS methodology is suitable for fitting the distribution of a single variable when no explanatory variables are included in the model. Likewise, GAMLSS is highly recommended in the case of fitting distributions with a certain degree of asymmetry. Surgery and Outpatien consultations variables are positively skewed and leptokurtic. Therefore, we fit a wide variety of models on the positive range of the variables and the optimal model will be selected based on goodness-of-fit criteria.

The selection of the appropriate distribution is done in two stages, the fitting stage, and the diagnostic stage:

- The fitting stage involves the comparison of different fitted models using a generalised Akaike information criterion (GAIC). The GAIC is defined as $\mathrm{GAIC}(k) = -2\mathrm{l} + \mathrm{k} \times df$ where l is the log-likelihood function, $df$ are the effective degrees of freedom, and k is a constant. We refer to $-2\mathrm{l}$ as the global deviance. The selected model is the one with the smallest $\mathrm{GAIC}(k)$ value. The Akaike information criterion (AIC), Akaike (1974), and the Bayesian information criterion (BIC), Schwarz (1978), are special cases of the GAIC(k) corresponding to $\mathrm{k} = 2$ and $\mathrm{k} = log(n)$, respectively. The two criteria, AIC and BIC, are asymptotic approximations to the average predictive error. In practice, it is found that the AIC is less restrictive than the BIC on model selection, see Voudouris et al. (2012). Similarly, when $\mathrm{k} = 3.84$ the GAIC(k) corresponds to a Chi-squared test with one degree of freedom for a single parameter. In general, the greater the number of parameters in the model, the more easily it fits the data and the lower its log-likelihood, but in turn, the greater its risk of overfitting. This drawback is avoided using the GAIC(k) which incorporates a penalty k for each degree of freedom.
- The diagnostic stage involves the use of *worm plots*. Worm plots were introduced by Buuren and Fredriks (2001) and are detrended normal Q-Q plots of the quantile residuals (i.e., *z*-scores). The worm plot allows the detection of inadequacies in the model, globally or within a specific range (intervals) of an explanatory variable. Buuren and Fredriks (2001) proposed fitting cubic models to each of the detrended Q-Q plots, with the resulting constant, linear, quadratic and cubic coefficients, $\hat{b}_0, \hat{b}_1, \hat{b}_2, \hat{b}_3$, indicating differences between the empirical

and model residual mean, variance, skewness and kurtosis, respectively, within the range in the Q-Q plot. The absolute values of $\hat{b}_0$, $\hat{b}_1$, $\hat{b}_2$, $\hat{b}_3$ are categorized as misfits when they excess the threshold values, 0.10, 0.10, 0.05, 0.03, respectively.

## 3. Spanish National Health System

The Spanish public health system is characterized by being financed by taxes, universal and guarantees free health services at the time of use. The right to health protection and health care for all its citizens is included in the Spanish Constitution of 1978 in its article 43. Regarding health care, two levels must be distinguished: primary care which access is spontaneous, and the assistance takes place in health centers and local clinic, and specialized care which access is by indication of primary care doctors and the assistance takes place in specialty centers and hospitals.

There is a political decentralization of the health system in 17 "Autonomous Communities" (administrative partition of the territory, hereinafter regions), so that health care constitutes a non-contributory benefit financed by taxes and being included in each region general budget. The existence of 17 health services, each with its own features, is the essence of health decentralization, a government strategy that aims to bring the decision-making center closer to citizens for a better response to their needs. These regions are coordinated through the Interterritorial Council of the SNHS. The report of the Spanish Ministerio de Sanidad, Política Social e Igualdad (2008) defines the SNHS as "the coordinated group of health services of the State Administration and of the regions, that integrates all the functions and health benefits that, according to the law, are the responsibility of the public authorities".

The Spanish Ministerio de Sanidad publishes information on waiting times for specialized care (but not for primary care) every 6 months, providing both national data and data for the 17 regions. Even though the Real Decree 605/2003 establishes measures for the homogeneous treatment of information on waiting lists in the SNHS, the regions provide heterogeneous information with different disaggregation detail on their web pages, making it difficult to compare data between different regions. For each region there are three waiting lists: surgery (for non-urgent surgeries), outpatient consultations (first consultations with specialists), and diagnostic tests, which serve as the basis for computing different waiting times and another series of indicators.

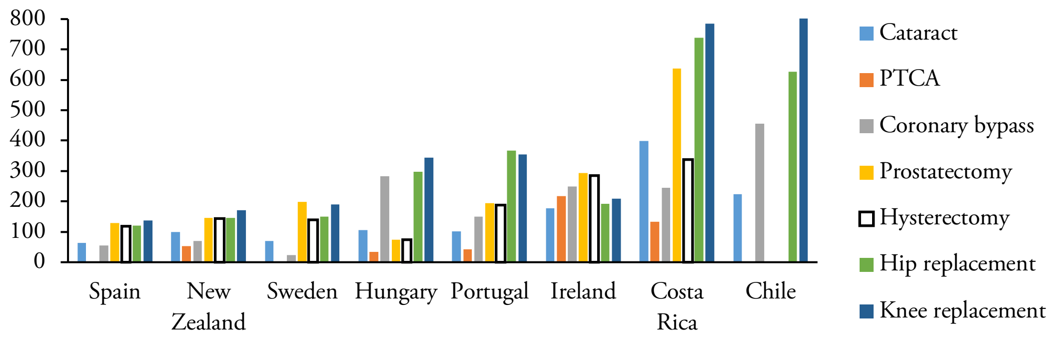
In Spain there are several regulations and action plans regarding waiting lists. Royal Decree 16/2003, on the cohesion and quality of the SNHS, regulates health services and their essential aspects, such as those referring to guarantees of accessibility, mobility, access time, information, security, and quality. This Law authorizes regions to define the maximum access times to their portfolio of service. After this rule, the regions grant patients the right to subcontract private health services when the waiting lists exceed maximum waiting times and when the service included is within the category of "guaranteed". In this sense, Royal Decree 1039/2011 establishes the criteria to guarantee a maximum time of access to the SNHS health benefits of 180 days for certain non-urgent surgeries, as well as authorizes the regions to shorten these times.

Currently, many regions have reduced these waiting times in certain surgeries, for example, with those related to oncological surgeries, as well as in first outpatient consultations. Furthermore, the problem of waiting lists/times translates into a significant economic and social cost. For example, when the maximum guaranteed deadlines are not met, the health system of each region will bear the expenses caused by the patient's right to receive care or surgery in a private center. In addition, health resources must be balanced from both the supply side and the health demand side to not fall into situations of inefficiency, for example, hiring personnel for periods of high demand results in an inefficient cost in periods of low demand.

## 3.1. Health systems by regions

Spain has always boasted of having a very good health system and great professionals in its ranks. In fact, according to the SNHS, 7 out of 10 people consider that the Spanish health system works well. Analyzing data from the OECD Health Statistics[6] we can see in Figure 1 the mean waiting times of patients on the lists in 2021, the most recent data. The bar plot includes all the country information available for Chile, Costa Rica, Hungary, Ireland, New Zealand, Portugal, Spain and Sweden about the following selected elective surgeries: cataract, percutaneous transluminal coronary angioplasty (PTCA), coronary bypass, prostatectomy, hysterectomy, hip replacement and knee replacement. We can see that Spain presents the smallest waiting times compared with the rest of countries being analized. Countries with the largest waiting times are Costa Rica and Chile, the latter having the largest waiting times for knee replacement. Knee replacement and hip replacement are the surgeries with largest waiting times across countries, whereas cataract and PTCA the ones with shortest waiting times. The smallest wainting times in Spain correspond to coronary bypass and cataract, and the largest to knee replacement and prostatectomy.

**Figure 1.**
**Waiting times of patients on the lists 2021: Mean (days)**




**Source:** Authors' elaboration. PTCA means percutaneous transluminal coronary angioplasty.

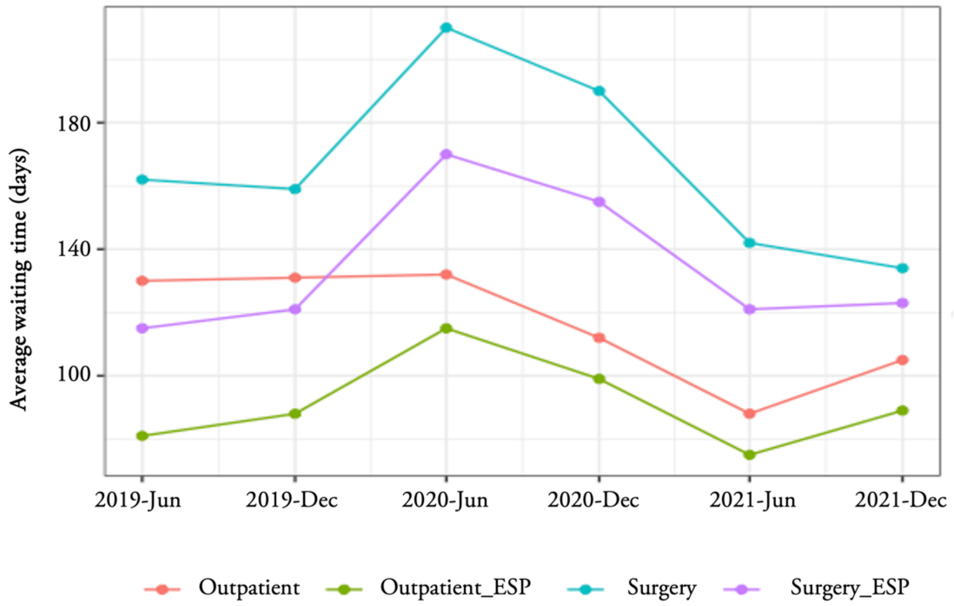
Figure 2 shows how the average surgical waiting times (mean delay in days of patients pending non-urgent surgery intervention) in Andalusia (Surgery), from June 2019 to December 2021, are much higher than the national average (Surgery_ESP). Regarding outpatient consultations, the average waiting times (average delay in days of patients pending a first visit to the specialist) in Andalusia (Outpatient) are also higher than the national data (Outpatient_ESP) in the analyzed period, but with delays substantially lower than Surgery. If we compare the behavior of both variables in the pre- and post-pandemic situation in Andalusia, we observed that surgery waiting times from June 2020 begin a downward trend, reaching levels lower than 2019, an aspect that is not ratified at the national level, with data higher than the pre-pandemic in both variables.

However, it should be noted that in the COVID-19 period[7], year 2020, the patient guarantee system was revoked (maximum response times by the health system), both in outpatient consultations and in surgeries at the AHS and at the national level. Although both delay times return to lower data than the pre-pandemic at the end of June 2021, in outpatient consultations there is a certain tendency to progressively increase waiting times, specifically, in June 2022 the average waiting time is 107, two days on average higher than the data for December 2021.

[6] Data source: Health care utilization at https://www.oecd.org

[7] See De Pablos Escobar and Centeno (2021) for a deeper understanding of the impacts of COVID-19 on surgical waiting list in Spain.

FIGURE 2.
**Average waiting time evolution for Andalusia and Spain**




**Source:** Authors' elaboration.
**Notes:** Outpatient and Surgery refers to Andalusia data, Outpatient_ESP and Surgery_ESP refers to Spanish data.

Figure 3 presents a comparison at the regional level which provides us with the following information. According to the SNHS as of December 31, 2021, the latest data available at the national level[8], the average waiting time in Spain for patients pending non-urgent surgery is 123 days, the regions with the worst situation are Aragon (183) and Catalonia (156). Andalusia appears in an intermediate zone with 128 days of waiting on average. On the other hand, the best-placed regions, below the average data for Spain, are the Basque Country (71) and the Community of Madrid (73)[9]. Patients awaiting surgery in Andalusia are 122,959 (second worst value after Catalonia) of the 706,740 existing in Spain on that date. In the rate per 1,000 inhabitants, this represents 15 waiting patients per 1,000 inhabitants, a data slightly lower than the national average (15.39). In this sense, Cantabria is the one with the highest rate, 23.73, closely followed by Extremadura (23.70).

Regarding the average outpatient consultations waiting time for Spain the data is 89 days[10]. The best-placed regions are the Basque Country (34), the Balearic Islands (51), and Galicia and the Community of Madrid, both with (56)[11]. The worst placed with data above the national average are Aragon (160), Canarias (118), Navarra (109) and Andalusia (105). The national data for patients on the waiting list for outpatient consultations per 1,000 inhabitants is 77.23, with Andalusia having the worst data in all of Spain, 106.49 patients on the waiting list per 1,000 inhabitants, followed by Navarra with a rate of 92.11. The national data for pending patients on the waiting list for outpatient consultations is 2,809,150, of which 873,047 are Andalusians, the highest data by region, a data that increases in June 2022 to 906,618.

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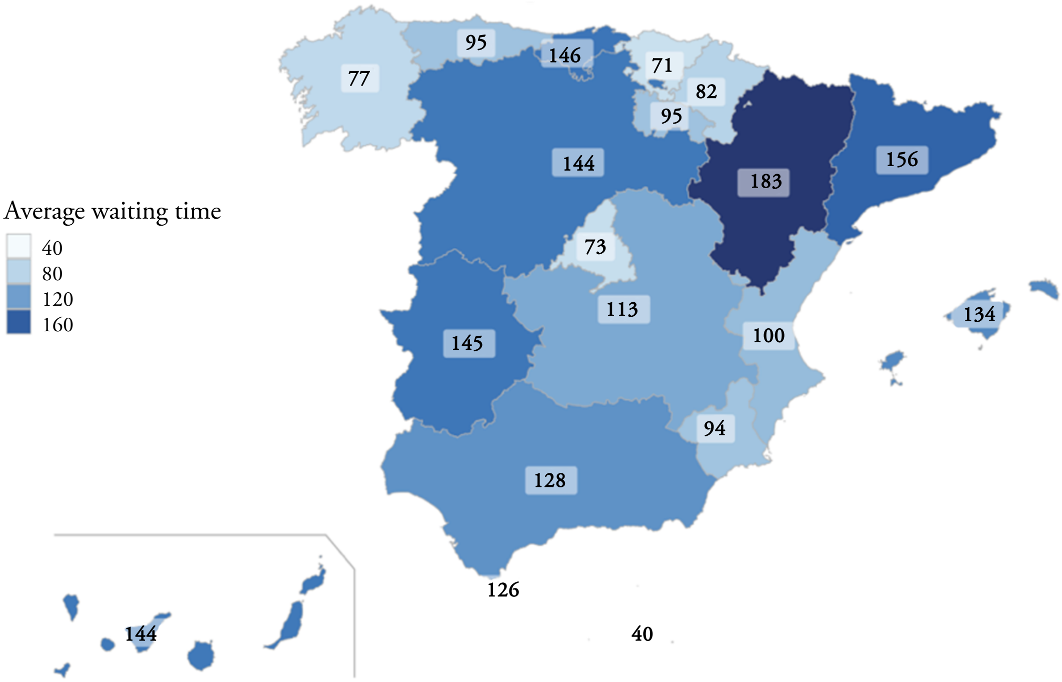
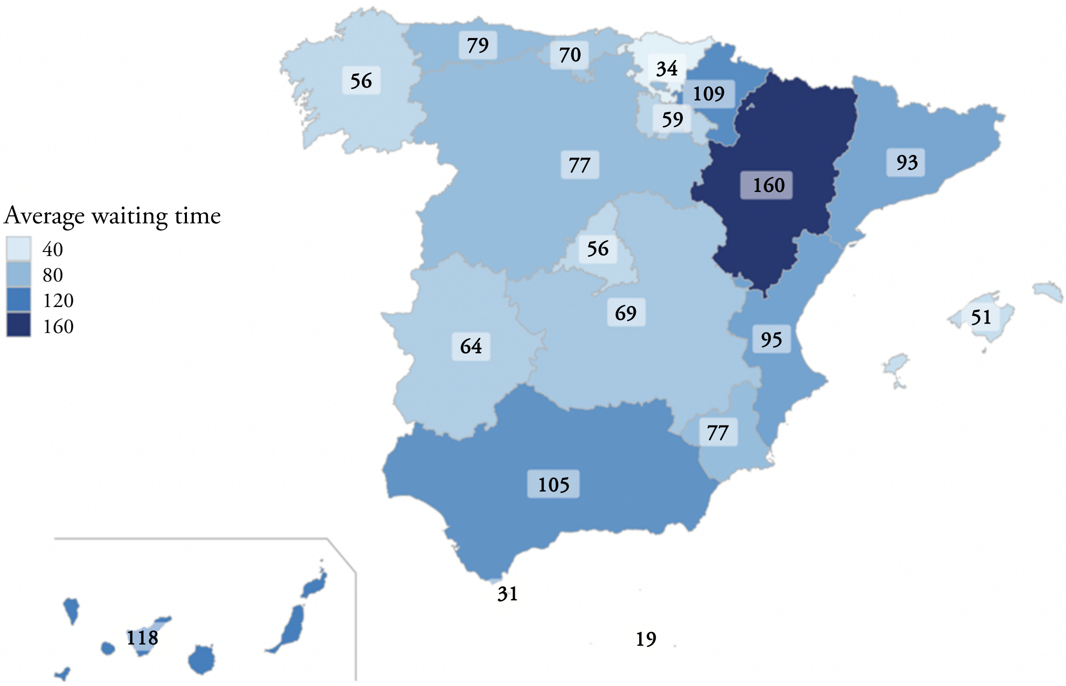
[8] Data source:
https://www.sanidad.gob.es/estadEstudios/estadisticas/inforRecopilaciones/docs/LISTAS_PUBLICACION_dic21.pdf
[9] The Autonomous City of Melilla has the shortest average waiting time in Spain, 40 days, but for its part, Ceuta has an average waiting time of 126 days.
[10] Data source:
https://www.sanidad.gob.es/estadEstudios/estadisticas/inforRecopilaciones/ListaEsperaInfAntCCAA.htm
[11] The Autonomous Cities of Melilla (19) and Ceuta (31) are those with the fewest waiting days.

FIGURE 3.
**Regional average waiting times (days) in Spain, December 31, 2021.**

**Surgery**




**Outpatient consultations**




**Source:** Authors' elaboration.

The relative situation of Andalusia with respect to the rest of the regions is not one of the worst, both waiting times in June 2022 being maintained at levels below the pre-pandemic. However, in terms of density for outpatient consultations, it reaches the worst data as of December 31, 2021. The situation of waiting lists is worrying in this community, with values much higher than the national ones.

Finally, it should be noted that Andalusia, for the latest available data, June 2022, has 150,034 pending patients awaiting surgery compared to 906,618 awaiting first outpatient consultations. In contrast, the overall data for the mean surgical delay (118 days) is slightly higher than the mean delay for outpatient consultations (107 days). Analysisng data by regions, we must point out that having the largest number of pending patients on a waiting list does not necessarily entail longer waiting times.

We just consider data from 2019-2022 in Section 3 in order to represent the average waiting time evolution for Andalusia and Spain. The analysis by hospital carried out from Section 4 onwards is made using the last available crosssectional data in June 2022.

## 4. Andalusian hospitals

Given the role that hospitals play in the phenomenon of waiting lists and, specifically, in waiting times, we will focus on modelling this last variable at the hospital level for the entire set of Andalusian public hospitals, and four concerted hospitals[12] which waiting times are considered by the AHS. Andalusian public hospitals are divided into four categories: *regional* hospitals, available to the entire region and having all kinds of medical specialties. *Specialities* hospitals, which are provincial and cover many specialties. The so called *comarcal* hospitals, available for the population that lives less than 1 hour away and having basic specialties. The *high-resolution* hospitals, which serve the population that lives less than 30 minutes away and have basic specialties. Throughout the text, we refer to all hospitals under study as public hospitals.

The hospital catalog prepared by the Spanish Ministerio de Sanidad (2022), as of December 31, 2021, shows that there are 832 hospitals in Spain, most of them located in Catalonia (204), Andalusia (131) and the Community of Madrid (90). In Andalusia, 73 hospitals are public and 58 are private. The SNHS accounts for each of the registered hospitals although some of them, at an organizational level, may form part of a complex. Thus, for example, the Regional University Hospital of Málaga is a complex that includes three hospitals: Civil Hospital, Materno-Infantil Hospital and General Hospital of Málaga. This fact happens in the 8 Andalusian provinces. This greater breakdown contrasts with the data published by the AHS which provides only the aggregate data of the complex, so the sample of hospitals of the AHS analyzed here is decreased to 52. As the publications are available every six months (data as of June 30 and December 31), for each of the variables analyzed, the average surgery waiting times and the average outpatient consultations waiting times, we consider the most recent data, June 2022.

Although the regions must have an information system on the waiting lists for outpatient consultations, diagnostic/therapeutic tests, and surgical interventions, the AHS only publishes data for surgical and outpatient lists.

Descriptive statistics of average waiting times can be seen in Table 1, for data up to June 2022. The range of Outpatient consultations, in days, is greater than the Surgery one, with means greater than the medians for each of the variables. This feature can be seen in the boxplots in Figure 4, meaning that the two data series are comprised of abundant of short waiting times and relatively fewer long-waiting times. All this denotes the marked positive asymmetry of both distributions. It should be noted that the sample of hospitals for Outpatient consultations have increased by one unit by including the Benalmadena High-resolution Hospital, Málaga ($n = 52\ hospitals$). For both variables we found atypical data, in the case of Surgery: Regional de Málaga U.H. with 193 days; Torrecárdenas U.H., a specialty hospital in Almería, with 191 days; Virgen de las Nieves U.H., regional hospital in Granada with 187 days, and Jaén U.H., specialty hospital with 176 days of waiting[13].

[12] Three concerted hospitals are in the province of Cádiz and one in the province of Huelva.
[13] U.H. meaning University Hospital throught the text.

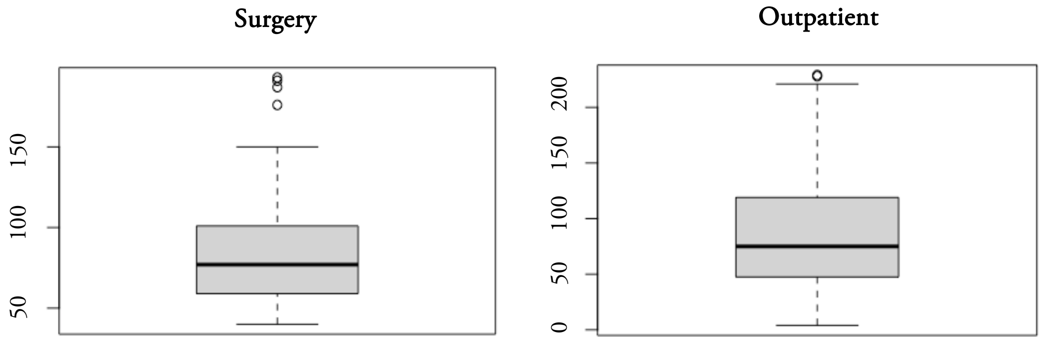
**TABLE 1.**
**Descriptive statistics of average waiting times in Andalusian hospitals. June 2022**

| Dataset | Min | Max | 1stQu | Median | Mean | 3rdQu | n |
|---|---|---|---|---|---|---|---|
| Surgery | 40 | 193 | 59 | 77 | 87.33 | 101 | 51 |
| Outpatient | 4 | 229 | 47.75 | 75 | 87.63 | 116 | 52 |

**Notes:** Surgery refers to average surgery waiting time (days) and Outpatient refers to average outpatient consultation waiting time (days).
**Source:** Authors' elaboration.

On the other hand, the atypical ones in Outpatient consultations correspond to: Linea de la Concepción Hospital, comarcal hospital in Cádiz (229 days), Alto Guadalquivir Hospital, comarcal hospital in Jaén (228 days) and High-Resolution Hospital of Guadix in Granada (221 days)[14].

**FIGURE 4.**
**Boxplots of Surgery and Outpatient consultations average waiting times (in days) for Andalusian hospitals**




**Source:** Authors' elaboration.

Table 2 presents the hospitals with a waiting list of more than 6,000 patients awaiting a non-urgent surgical intervention, *Surgery*, and the hospitals with a waiting list of more than 30,000 pending patients for Outpatient consultations, *Outpatient*. Hospitals with white spaces do not exceed those limits. Analysing Surgery data, it is important to note that the hospitals with the longest waiting lists do not correspond to those with the longest average delays and, contrary to what one might think, regional hospitals are not always the ones with the longest waiting times. The longest Outpatient consultations waiting lists are in Málaga, specifically in the U.H. Regional de Málaga and the U.H. Virgen de la Victoria, which do not correspond to the hospitals with the longest average delay in Andalusia (the atypical ones). All this leads us to conclude that the longest average delays are not accompanied by the longest waiting lists, and that the highest values of waiting times predominate in specialties hospitals.

[14] In the case of Surgery, hospitals with atypical average waiting times have in common that they are hospital complexes, and of a regional or specialized type, but in the latter case, the provinces in which they are located do not have a regional reference hospital. In the case of Outpatient consultations hospitals with atypical average waiting times are of relatively recent creation and specialized in diagnoses that require high-resolution technological equipment.

TABLE 2.
**Surgery and Outpatient consultations waiting lists and average waiting times for Andalusian hospitals. June 2022**

| | | | Surgery | | Outpatient | |
|---|---|---|---|---|---|---|
| Hospitals | Type | Province | AWT (days) | TWL (patients) | AWT (days) | TWL (patients) |
| Torrecárdenas U.H. | Specialties | Almería | 191 | 6,807 | 82 | 30,872 |
| Reina Sofía U.H. | Regional | Córdoba | 112 | 10,760 | | |
| Virgen de las Nieves U.H. | Regional | Granada | 187 | 10,591 | | |
| Juan Ramón Jiménez U.H. | Specialties | Huelva | 128 | 6,613 | 140 | 37,867 |
| Jaén U.H. | Specialties | Jaén | 176 | 7,978 | 183 | 48,959 |
| Regional de Málaga U.H. | Regional | Málaga | 193 | 9,206 | 89 | 67,916 |
| Virgen de la Victoria U.H. | Specialties | Málaga | 68 | 6,448 | 130 | 78,037 |
| Virgen del Rocio U.H. | Regional | Sevilla | 111 | 13,323 | 57 | 49,799 |
| Virgen de Valme U.H. | Specialties | Sevilla | 88 | 6,379 | 107 | 31,103 |
| Virgen Macarena U.H. | Regional | Sevilla | 98 | 9,576 | 78 | 45,368 |
| Jérez de la Frontera U.H. | Specialties | Cádiz | | | 105 | 31,105 |
| San Cecilio U.H. | Specialties | Granada | | | 126 | 36,950 |
| Costa del Sol Hospital | Specialties | Málaga | | | 96 | 37,810 |

**Notes:** University Hospital (U.H.), Average waiting time (AWT), Total waiting list (TWL). Being the two largest values in bold letters.
**Source:** Authors based on AHS data.

## 5. WAITING TIMES PROBABILITY DISTRIBUTION ANALYSIS

We first analyze in Figure 5 the Cullen and Frey graphs for Surgery and Outpatient consultations distributions, being the yellow points the bootstrap samples. The distributions are positively skewed (values greater than 0), Surgery presents a positive skewness (1.35) slightly higher than Outpatient consultations (1.17). Both distributions are leptokurtic with kurtosis coefficients greater than 3, Surgery (4.51) and Outpatient consultations (4.21), that is, more pointed than normal. Therefore, the Cullen and Frey graphs recommend fitting typical distributions for markedly positive asymmetric data, such as Gamma, Log-normal and Weibull.

### 5.1. SURGERY WAITING TIMES

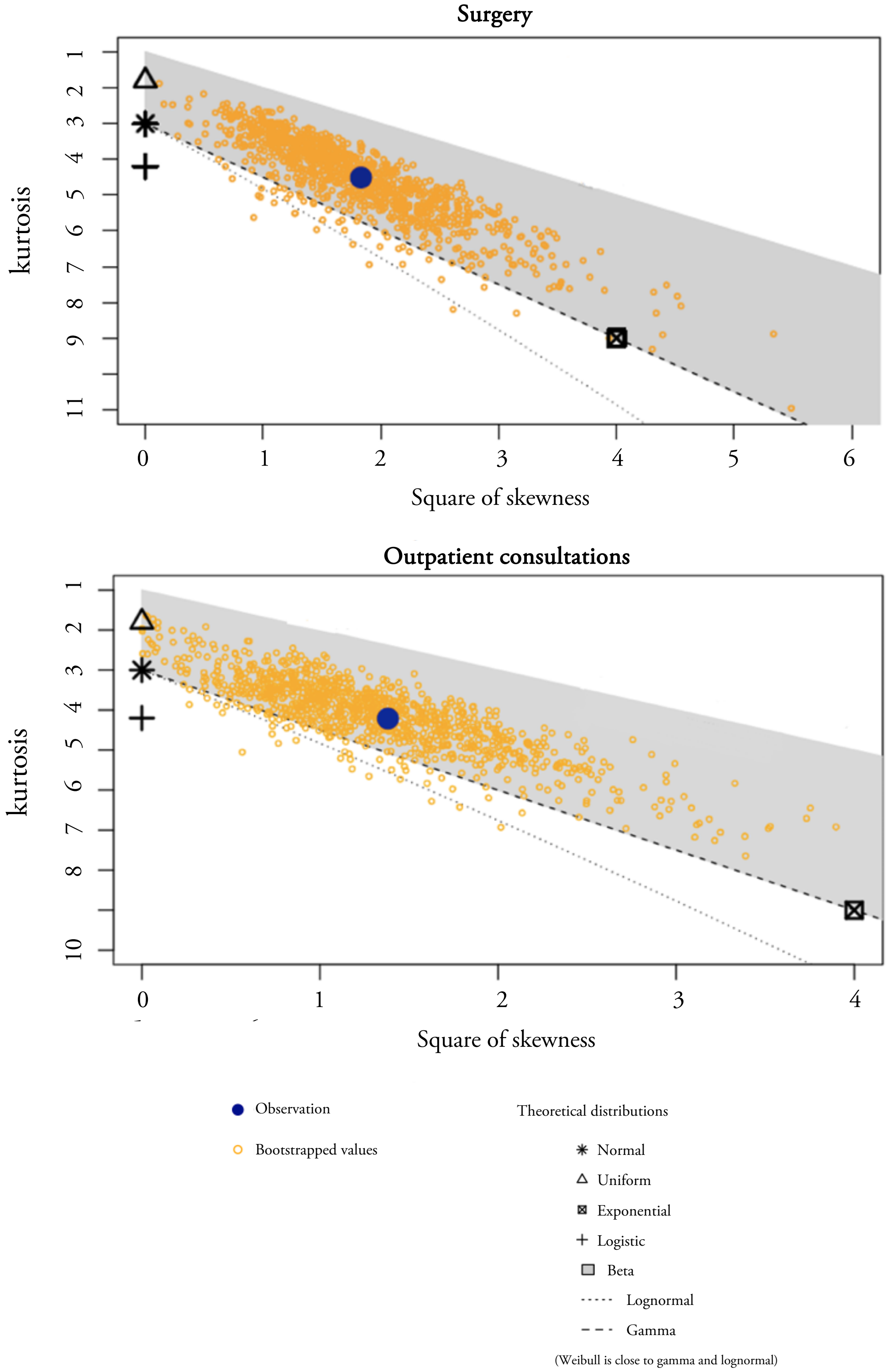
We analyzed the average surgery waiting time optimal distribution of Andalusian public hospitals as of June 30, 2022, through the GAMLSS methodology. For Surgery, variable with positive range, from zero to infinity, and continuous, the data have been fitted to the 23 distributions provided by the R package GAMLSS, see Stasinopoulos and Rigby (2008). The fitted distributions can contain from one to four parameters and the appropriate model for the data is selected through the three information criteria inherent to the GAIC(k): AIC, Chi-squared and BIC, see Table A1 in Appendix A.

These criteria are increasingly recurrent in the literature when selecting models[15], since they allow considering a large set of distributions with different numbers of parameters to fit the same data, always keeping in mind that it is possible that the true model is not found in the set of those considered. However,

[15] Adjustment criteria based on tests with a certain level of significance, such as those of Kolmogov-Smirnov, Cramer-von Mises and Anderson-Darling, are not recommended when comparing models with different degrees of freedom, that is, with a different number of parameters.

by selecting the largest possible number of candidate models, and based on the nature of the study variable, this drawback can be overcome, on the basis that a model cannot perfectly describe real data.

**FIGURE 5.**
**Cullen and Frey graphs for Surgery and Outpatient consultations distributions**




**Source:** Authors' elaboration.

The inverse gamma (IGAMMA) is selected as the most appropriate distribution achieving the lowest value in each of the three criteria. We must point out that the models pre-selected by Cullen and Frey graph (LOGNO, GA and WEI) are not in the top positions.

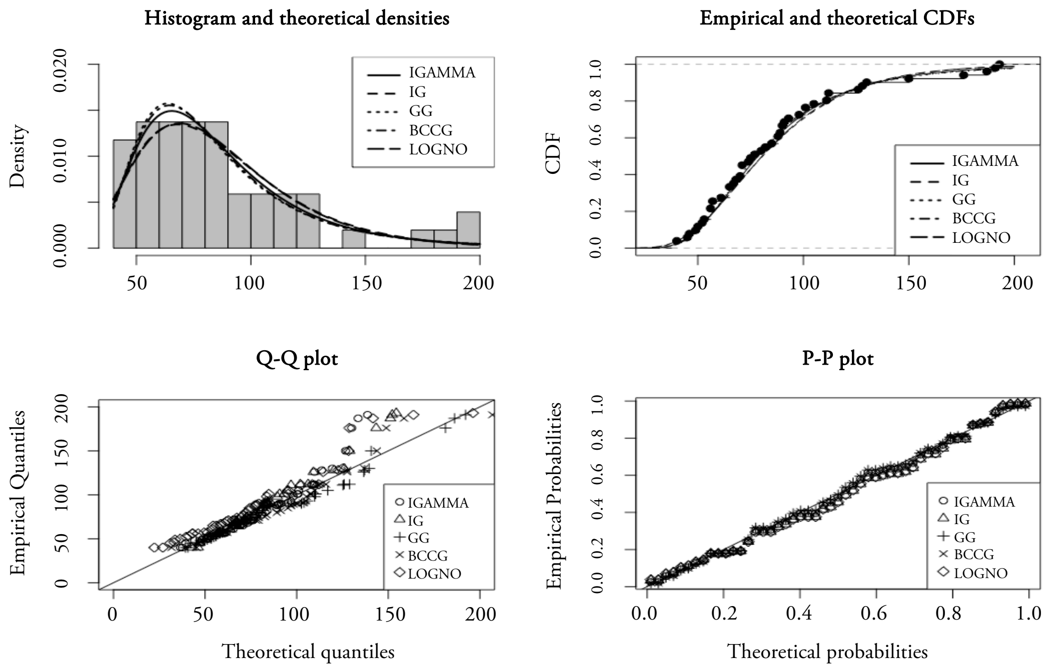
Figure 6 shows four goodness-of-fit plots of the first five distributions according to AIC: IGAMMA (Inverse Gamma, two parameters), IG (Inverse Gaussian, two parameters), GG (Generalized Gamma, three parameters), BCCG (Box-Cox Cole and Green, three parameters) and LOGNO (Log-normal, two parameters).

In general, the models have an important relative quality to fit Surgery data, but in the CDF graph it is observed that the IGAMMA (with location paremeter, the mode, $\mu = 65.42$ days, and scale parameter, $\sigma = 0.38$ days) fits better the central part, as well as the tails of the distribution. We must point out that in the distribution of Surgery atypical data have not been excluded.

The reason is that we are interested in testing models in atypical datasets with marked asymmetries and with parameters that include the express modeling of asymmetry and kurtosis such as BCCG and BCPE (Box-Cox Power Exponential), with three and four parameters, respectively.

The second stage of the GAMLSS methodology offers a second filter based on the study of residuals to verify if the selected model turns out to be optimal. In Table 3 we note that the (normalized quantile) residuals of IGAMMA and IG probability models behave well, e.g., their means are nearly zero, variances nearly one, coefficients of skewness near zero and coefficients of kurtosis near 3. Hence the residuals are approximately normally distributed as they should be for an adequate model.

**FIGURE 6.**
**Goodness-of-fit plots for Surgery data**




**Notes:** IGAMMA (Inverse Gamma), IG (Inverse Gaussian), GG (Generalized Gamma), BCCG (Box-Cox Normal) and LOGNO (Log-normal).
**Source:** Authors' elaboration.

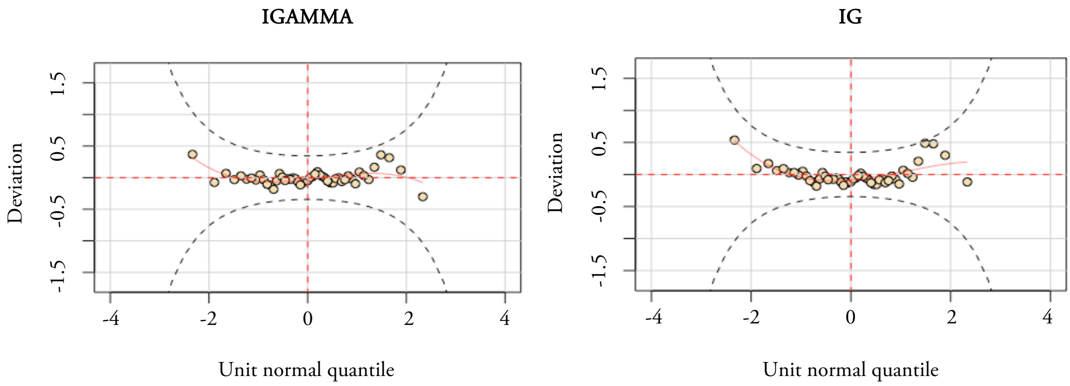
**Table 3.**
**Summary of the quantile residuals for Surgery**

| | Inverse Gamma | Inverse Gaussian |
|---|---|---|
| **Mean** | -0.0005 | -0.0079 |
| **Variance** | 1.0201 | 1.0162 |
| **Coef. of skewness** | 0.1462 | 0.4210 |
| **Coef. of kurtosis** | 2.4032 | 2.6174 |

**Source:** Authors' elaboration.

Figure 7 presents the worm plots for Surgery of the IGAMMA and IG distribution models. Since all the observations fall in the acceptance region inside the two elliptic curves the models appear to fit well. Moreover, the lack of quadratic and cubic shape of the residuals indicates that the empirical skewness and kurtosis are appropiately captured by the two models.

**Figure 7.**
**Worm plots of the Inverse Gamma and Inverse Gaussian distribution models for Surgery**




**Source:** Authors' elaboration.

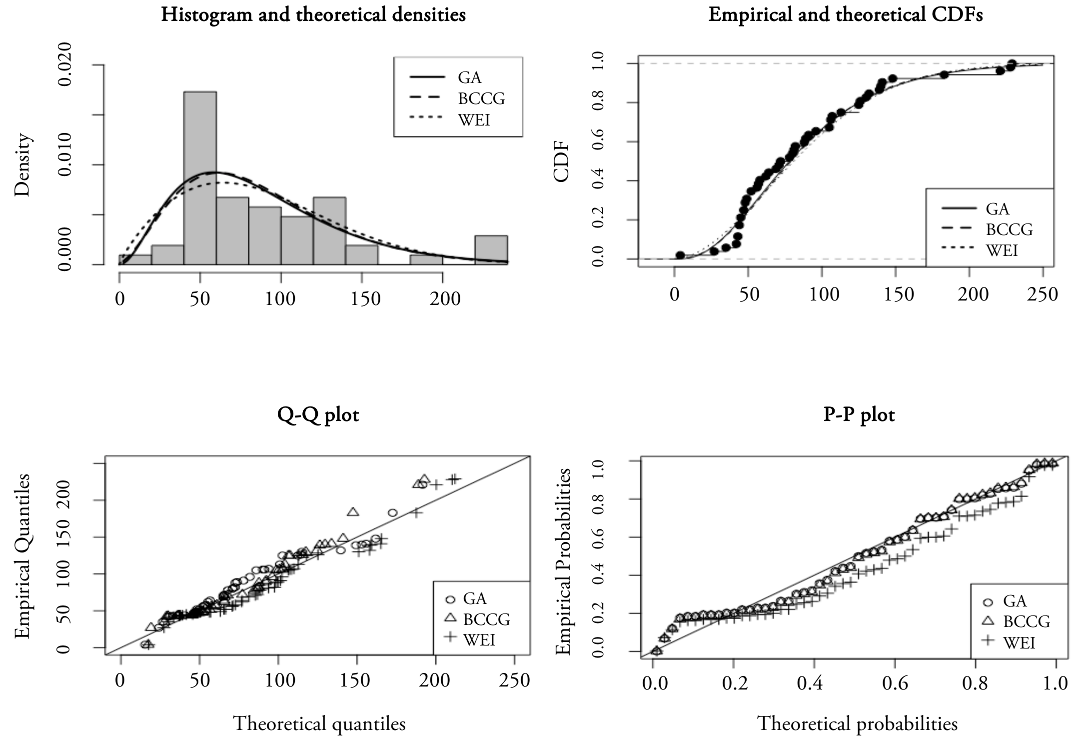
We highlight the slightly better behavior of the IGAMMA distribution, the residuals are more settled (less curved) on the red dashed line, ideally, the resulting values should be zero. For all these reasons, the inverse gamma distribution is the optimal of the 23 analyzed, to fit the data on average Surgery waiting times for the Andalusian Health System hospitals, according to the GAMLSS methodology, GAIC criteria.

## 5.2. Outpatient consultations waiting times

As in the previous case, we find the distribution that best fits the average outpatient consultations waiting times of the Andalusian public hospitals (Outpatient consultations). For Outpatient consultations, variable with positive and continuous range, the data, including outliers, have been adjusted to the 23 distributions. In this case the Gamma distribution (GA) occupies the first position according the three criteria, AIC, Chi-squared and BIC, see Table A2 in Appendix A. The three information criteria give different orderings of the models that best fit the data. Following the AIC criterion, Figure 8 presents the four goodness-of-fit plots of the first three distributions according to AIC: the GA (Gamma, two parameters), BCCG (Box-Cox Cole and Green, three parameters) and WEI (Weibull, two parameters) distributions.

The best fitting distribution turns out to be a biparametric model, such as the Gamma model (with location paremeter, the mean, $\mu$ = 87.63 days, and scale parameter, $\sigma$ = 0.58 days).

**FIGURE 8.**
**Basic goodness-of-fit plots for Outpatient consultation data**




**Source:** Authors' elaboration.
**Notes:** GA (Gamma), BCCG (Box-Cox Normal) and WEI (Weibull).

The analysis of the residuals confirms previous results, see Table 4, where the summary of the quantile residuals points to a Normal standardized distribution, and Figure 9 displaying the correspoinding worm plot.

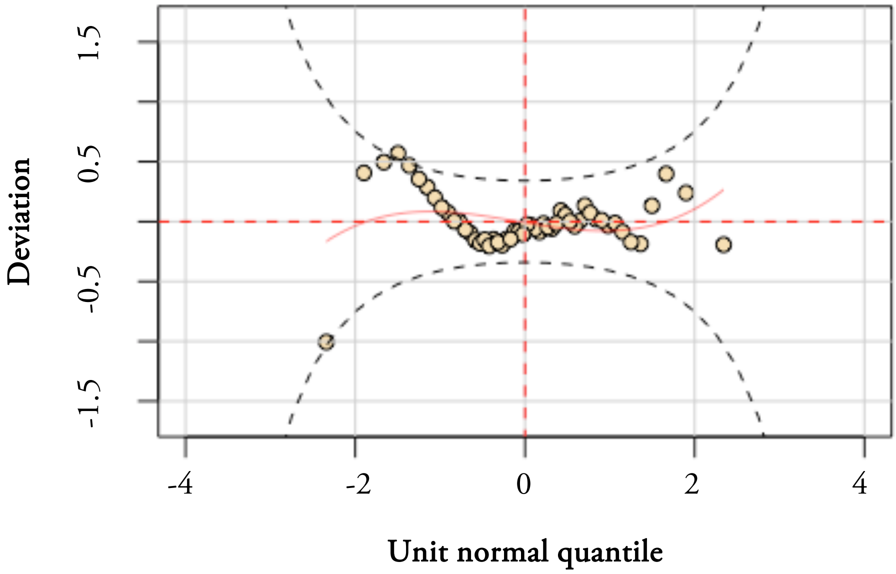
**TABLE 4.**
**Summary of the quantile residuals for Outpatient consultations**

| | Gamma |
|---|---|
| **Mean** | 0.0023 |
| **Variance** | 1.0211 |
| **Coef. of skewness** | -0.1633 |
| **Coef. of kurtosis** | 3.9803 |

**Source:** Authors' elaboration.

If the model is correct, we would expect approximately 95% of the points to be between the two elliptic curves and 5% outside. In our case, the percentage of outside observation is below 5%, since there is only one case (1.93%). The small negative slope at the beginning of Figure 9 indicates some difficulty for modeling the kurtosis, see Stasinopoulos et al. (2017).

**FIGURE 9.**
**Worm plots of the Gamma distribution model for Outpatient consultations**




**Source:** Authors' elaboration.

The behavior of Surgery and Outpatient consultations waiting times are similar to other waiting times variables. For example, lengths of stay for a patient in the hospital were fitted by Marazzi et al. (1998) to three probability distributions, Weibull, Gamma and Log-normal, identifying the Log-normal distribution as the one that best fitted most of the samples.

## 5.3. Empirical application

The adjustment of an optimal probability model to the observed data constitutes an instrument to estimate theoretical probabilities that will allow us to analyze the data in different scenarios. Table 5 shows the estimated probabilities that an Andalusian public hospital exceeds a given average waiting time, both for Surgery (90, 120, 180 and 365 days), and for Outpatient consultations (60 days).

In the AHS there is an extensive list of surgical interventions with a maximum guaranteed response time of 90, 120 and 180 days, as well as for the first external consultations of 60 days. Failure to comply with these response guarantee periods may constitute an additional cost for the AHS since the affected patient may be treated in the private health system and the corresponding expenditure would be covered by the AHS.

We can see in Table 5 that the probability of an Andalusian public hospital exceeding an average waiting time of 365 days is almost null (0.0007). Therefore, as the waiting time threshold decreases, the probability increases, for example, the probability that a hospital exceeds 90 days on average is 36.44%. The probabilities corresponding to Surgery together with their corresponding 95% confidence intervals (between brackets) have been estimated using the IGAMMA model. The second column presents the estimated number of Andalusian hospitals that are expected to exceed the guaranteed response times. It is estimated that approximately 19 ($51 * 0.3644$) hospitals exceed the average waiting time of 90 days, the corresponding observed data is 17 hospitals, see Table B1 in Appendix B. There are no Andalusian public hospitals that exceed the average waiting time of 365 days for surgical waiting, neither with the estimated theoretical model nor in the observed data. Exceeding 180 days of waiting times, a total of 1.49 hospitals are estimated for Andalusia, and the observed data is 3[16] as of June 2022.

**Table 5.**
**Estimated waiting times/list for Surgery and Outpatient Consultations for Andalusian hospitals. June 2022**

| | Probabilities | Hospitals | Waiting list (patients) |
|---|---|---|---|
| Surgery (IGAMMA) | $P(w > 90) = 0.3644\ (0.17, 0.54)$<br>$P(w > 120) = 0.1520\ (0.04, 0.31)$<br>$P(w > 180) = 0.0292\ (0.003, 0.11)$<br>$P(w > 365) = 0.0007\ (1{,}28E-05, 0.0009)$ | 18.58<br>7.75<br>1.49<br>0.03 | 54,672.39<br>22,805.17<br>4,381<br>105 |
| Outpatient consultations (GA) | $P(w > 60) = 0.6609\ (0.6, 0.68)$ | 34.36 | 599,183.84 |

**Notes:** $w$ is the average waiting time measured in days. The observed waiting lists for Surgery and Outpatient consultations have 150,034 patients (51 hospitals) and 906,618 patients (52 hospitals), respectively. The 95% confidence intervals are between brackets.

Analyzing the observed data of the 8 Andalusian provinces, we find that Córdoba and Sevilla do not have hospitals exceeding the average waiting time of 120 days. We highlight the case of Córdoba with 6 hospitals and just one, Reina Sofía U.H. (112 days), exceeding the average waiting time of 90 days, see Appendix B, Table B1.

The total number of patients on the waiting list for Surgery is 150,034 patients, multiplying this number by the probabilities in the first column of Table 5 we obtain the estimated number of patients exceeding a certain threshold at Andalusian public hospitals in the third column. We observed that the estimated numbers of pending patients represent a considerable amount. Even in the case of having almost zero probabilities of waiting times, $P(w > 365)$, the estimated total number is 105 patients for the complex of Andalusian hospitals.

In the same way, and based on the gamma model, we have proceeded for Outpatient consultations, where both the probability of exceeding the average waiting time of 60 days (0.6609) and the estimated number of patients pending on the waiting list for the group of hospitals Andalusians (599,183.84) are much higher than those estimated for Surgery. This is also accompanied by a greater number of hospitals that are estimated to exceed that time, 34 hospitals, being the observed data 31 hospitals as of June 2022, see Table B2 in Appendix B. With respect to the observed data, all Andalusian provinces have most of their hospitals exceeding said threshold. We highlight again the case of Córdoba, since only one of its hospitals, Valle del Guadiato high-resolution Hospital, exceeds the 60 days on average.

As has already been commented throughout this study, Surgery waiting times are longer than those for Outpatient consultations, although the probabilities of exceeding the considered waiting times are lower for Surgery.

It should be noted that, for Surgery, the probability of exceeding, for example, 90 days on average, will include patients pending surgical procedures with different response guarantee periods of 90, 120 and 180 days, as well as patients without guarantee of response, since the average surgical waiting times used in this study includes both categories[17]. The estimated number of pending patients that exceed 90 days on

[16] The three hospitals are: Virgen de las Nieves U.H. (Granada), Torrecárdenas (Almería) U.H. and. Regional de Málaga U.H that are part of the hospitals with atypical waiting times seen in Section 4.

[17] The AHS in Decreto 209/2001, of September 18, establishes the guarantee of a surgical response period of 180 days for a total of 700 surgical procedures with their respective maximum prices to be paid by the public health administration to private health centers. Subsequently, in 2006, this period was reduced to 120 days for a total of 11 surgical procedures, and finally, in 2016, it was reduced to 90 days for certain cardiac surgical procedures. The maximum response guarantee period for first outpatient consultations is 60 days, including a wide range of medical specialties and if the consultation has been requested by a primary care doctor.

average is 54,672.39. This estimation could be considered by the AHS since many of these patients may be waiting to receive surgery that has a maximum response guarantee period, with the subsequent cost that this would entail for public health.

Another application of the methodology developed in this section can be obtained at the microdata level, where the observations under study are made up of patients on the waiting list at each hospital. Let us remember that, in our case, the observations are the hospitals, having available the average waiting times for each hospital, hence the estimates provided in this section are for the data of all Andalusian public hospitals.

The possibility of having microdata by hospital would allow estimating probabilities by different levels of disaggregation: estimating the distribution of waiting times for patients on the waiting list, with surgical procedures or first outpatient consultations, with a guarantee of response within the deadlines already commented; by age groups, and other socio-economic characteristics that the patients on the waiting list can provide.

According to Economic Theory, in markets where prices regulate supply and demand, long waiting lists could be avoided by paying a higher price in private healthcare. Nevertheless, in the case of Spain where there are no real prices that regulate the demand in public health, it is more difficult to find a balance between supply and demand. Assuming that waiting times/lists will always exist, we emphasize the role that knowledge of the optimal distribution of the waiting time variable can play in the appropriate management of material and human resources.

## 6. Discussion and conclusion

In a first analysis of the waiting times/lists, we find: first, there is a lack of positive correlation between waiting times and waiting lists. The average waiting times for Surgery are higher than those for Outpatient consultations, both at the regional level and in the hospital analysis for Andalusia. However, the number of pending patients on the waiting list is much higher in Outpatient consultations. Second, Surgery and Outpatient consultations studies for Andalusia show that there are hospitals with atypical waiting times, with no correlation between the type of hospital, waiting lists, or between waiting times. Third, the flexible GAMLSS methodology allows expanding the set of models for adjusting the data to a total of 23 distributions, with positive range and continuous, with different number of parameters, selecting through the GAIC(k) information criterion, the inverse gamma model as the optimal one for the average waiting times of Surgery and the gamma probability distribution for the average waiting times of Outpatien consultations.

As a result of these modeling, we find the following conclusions: the property of parsimony has prevailed in our study given that models with a lower number of parameters have been selected, despite using the AIC among the information criteria, which is usually more favorable to probability distributions with a greater number of parameters. We conclude that the models finally selected, inverse gamma and gamma, both biparametric, outperform models with parameters that include the express modeling of asymmetry and kurtosis, such as those of BCCG (Box-Cox Cole and Green) and BCPE (Box-Cox Power Exponential), with three and four parameters, respectively.

Both distributions, Surgery and Outpatien consultations average waiting times, adopt a markedly positive and leptokurtic asymmetric form, meaning that the two data series are comprised of abundant of short waiting times and relatively fewer long-waiting times. This result would rule out the normality assumption of linear models. These results are in line with those found in Abásolo et al. (2014a, 2014b) analyzing Spanish data, and in Siciliani et al. (2014) studying OECD countries.

For the Andalusian hospitals, it has been analyzed that surgical waiting times are longer than those for the first outpatient consultations, although the low estimated probabilities that exceed the different average waiting time thresholds for surgical interventions may be indicative of an efficient management of the Andalusian community to data from June 2022 and in the short term. This result would ratify the downward trend in average surgical waiting times in Andalusia from June 2020 to June 2022, the date on which a value lower than before the pandemic was reached. This is not the case for Outpatient consultations, with worse predictions both in estimated probabilities and in patients on the waiting list, constituting this health service a clear bottleneck problem for the AHS.

This methodology can also be applied to microdata, having the waiting times for each patient in a hospital. For example, using the optimal model, one can estimate the number of pending patients per hospital who will exceed a certain waiting time, specifically, the maximum times with guarantee of response.

We consider that the continuous technological advances in the computer field together with a good operating system for monitoring databases at the hospital level will facilitate, almost regularly, the optimal modeling of the waiting times distribution. This will avoid undesirable effects of waiting times, such as worsening illnesses, and the additional costs for exceeding waiting times with guarantees of response.

We find two limitations in this work. First, the AHS publishes the number of patients pending intervention or first outpatient consultation for each Andalusian public hospital, but regarding waiting times it provides the average data for each hospital, which could affect our estimates. Second, the difficulty of finding information on predictor variables explaining waiting times at the hospital level further reinforces the fact of finding a good model that adjusts waiting times. It is known that there are both internal and external indicators of the public health systems that affect waiting times/lists such as: the aging of the population that increases the prevalence and incidence; new technologies and developments that increase the demand by expanding the range of diseases that in previous years could not be treated; managerial or administrative deficiencies; availability of material and human resources; medical practice (priority setting) and missing data, see Abbing (2001). Other important indicators are sociodemographic characteristics, public spending on health, and the waiting list itself (bottlenecks). However, accessing all this information is difficult, even more at the hospital level, either due to a lack of data or because they are not published by the different public health systems.

Future lines of research would be to apply the GAMSLSS methodology to other regions or countries, if information is homogeneous, and to include explanatory variables in the model. One of the tough challenges for all researchers in this field is to study the effect of explanatory variables on waiting times. The flexibility of this methodology makes it a useful tool for selecting an optimal econometric model, bearing in mind that one of the most important modelling decisions for a GAMLSS model is the choice of the distribution for the response variable, see Stasinopoulos (2019).

To conclude, this work brings to light the social, economic, and political debate that both the lists and the waiting times cause in all societies and provides a suitable tool for estimating the provision of funds and material and personnel resources, lines of action that hospital managers must consider for future periods.

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## Appendices

### Appendix A

Tables in Appendix A show the results from the model selection according to GAIC for Surgery data (Table A1) and Outpatient consultations data (Table A2).

**Table A1.**
**Model selection according to GAIC for Surgery data**

| Distribution model | AIC | Distribution model | Chisq | Distribution model | BIC |
|---|---|---|---|---|---|
| IGAMMA | 499.5672 | IGAMMA | 503.2472 | IGAMMA | 503.4272 |
| IG | 501.1026 | IG | 504.7826 | IG | 504.9626 |
| GG | 501.2823 | LNO | 505.1697 | LNO | 505.3497 |
| BCCG | 501.4805 | LOGNO2 | 505.1697 | LOGNO2 | 505.3497 |
| BCCGo | 501.4805 | LOGNO | 505.1697 | LOGNO | 505.3497 |
| LNO | 501.4897 | GG | 506.8023 | GG | 507.0723 |
| LOGNO2 | 501.4897 | BCCG | 507.0005 | BCCG | 507.2705 |

**TABLE A1. CONT.**
**Model selection according to GAIC for Surgery data**

| Distribution model | AIC | Distribution model | Chisq | Distribution model | BIC |
|---|---|---|---|---|---|
| LOGNO | 501.4897 | BCCGo | 507.0005 | BCCGo | 507.2705 |
| GIG | 501.5672 | GIG | 507.0872 | GIG | 507.3572 |
| BCPEo | 502.7623 | GA | 509.1020 | GA | 509.2820 |
| BCPE | 502.7623 | BCPEo | 510.1223 | BCPEo | 510.4823 |
| GB2 | 503.2825 | BCPE | 510.1223 | BCPE | 510.4823 |
| BCT | 503.4805 | GB2 | 510.6425 | GB2 | 511.0025 |
| BCTo | 503.4805 | BCT | 510.8405 | BCT | 511.2005 |
| GA | 505.4220 | BCTo | 510.8405 | BCTo | 511.2005 |
| WEI2 | 514.1267 | WEI2 | 517.8067 | WEI2 | 517.9867 |
| WEI | 514.1267 | WEI3 | 517.8067 | WEI3 | 517.9867 |
| WEI3 | 514.1267 | WEI | 517.8067 | WEI | 517.9867 |
| exGAUS | 521.9391 | exGAUS | 527.4591 | exGAUS | 527.7291 |
| EXP | 559.9127 | EXP | 561.7527 | EXP | 561.8427 |
| GP | 561.9127 | GP | 565.5927 | GP | 565.7727 |
| PARETO2o | 561.9128 | PARETO2o | 565.5928 | PARETO2o | 565.7728 |
| PARETO2 | 561.9132 | PARETO2 | 565.5932 | PARETO2 | 565.7732 |

**Note:** BCCG (Box-Cox Cole and Green), BCCGo (BCCG but with log link for mu), BCPE (Box-Cox power exponential), BCPEo (BCPE but with log link for mu), BCT (Box-Cox-*t*), BCTo (BCT but with log link for mu), exGAUS (exponential Gaussian), EXP (exponential), GA (gamma), GB2 (generalized beta type 2), GG (generalized gamma), GIG (generalized inverse Gaussian), GP (generalized Pareto), IG (inverse Gaussian), IGAMMA (inverse gamma), LOGNO (log normal), LOGNO2 (mu as the median), LNO (log normal (Box-Cox)), PARETO2 (Pareto Type 2), PARETO2o (PARETO2 but sigma is the inverse of the sigma in PARETO2), WEI (Weibull), WEI2 (Weibull -proportional hazards), WEI3 (Weibull - $\mu$ the mean).

**Source:** Authors' elaboration

**TABLE A2.**
**Model selection according to GAIC for Outpatient consultation data**

| Distribution model | AIC | Distribution model | Chisq | Distribution model | BIC |
|---|---|---|---|---|---|
| GA | 547.4016 | GA | 551.0816 | GA | 551.3016 |
| BCCGo | 548.6138 | WEI3 | 552.3401 | WEI3 | 552.5601 |
| BCCG | 548.6138 | WEI2 | 552.3401 | WEI2 | 552.5601 |
| WEI3 | 548.6601 | WEI | 552.3401 | WEI | 552.5601 |
| WEI2 | 548.6601 | BCCGo | 554.1338 | BCCGo | 554.4638 |
| WEI | 548.6601 | BCCG | 554.1338 | BCCG | 554.4638 |
| GG | 549.3286 | GG | 554.8486 | GG | 555.1786 |
| GIG | 549.4016 | GIG | 554.9216 | GIG | 555.2516 |
| BCT | 549.8520 | BCT | 557.2120 | BCT | 557.6520 |
| BCTo | 549.8520 | BCTo | 557.2120 | BCTo | 557.6520 |
| BCPEo | 550.5529 | BCPEo | 557.9129 | BCPEo | 558.3529 |
| BCPE | 550.5529 | BCPE | 557.9129 | BCPE | 558.3529 |
| GB2 | 550.9089 | LNO | 558.2675 | LNO | 558.4875 |
| LNO | 554.5875 | LOGNO2 | 558.2675 | LOGNO2 | 558.4875 |
| LOGNO2 | 554.5875 | LOGNO | 558.2675 | LOGNO | 558.4875 |
| LOGNO | 554.5875 | GB2 | 558.2689 | GB2 | 558.7089 |

**Table A2. cont.**
**Model selection according to GAIC for Outpatient consultation data**

| Distribution model | AIC | Distribution model | Chisq | Distribution model | BIC |
|---|---|---|---|---|---|
| exGAUS | 561.6219 | exGAUS | 567.1419 | exGAUS | 567.4719 |
| IG | 568.8420 | IG | 572.5220 | IG | 572.7420 |
| EXP | 571.2103 | EXP | 573.0503 | EXP | 573.1603 |
| PARETO2 | 573.2103 | PARETO2 | 576.8903 | PARETO2 | 577.1103 |
| GP | 573.2103 | GP | 576.8903 | GP | 577.1103 |
| PARETO2o | 573.2104 | PARETO2o | 576.8904 | PARETO2o | 577.1104 |
| IGAMMA | 583.7848 | IGAMMA | 587.4648 | IGAMMA | 587.6848 |

**Note:** Acronyms are listed in Table A1.
**Source:** Authors' elaboration.

## Appendix B

Tables in Appendix B show the hospitals of the AHS that exceed the different waiting times, both for Surgery (see Table B1) and for Outpatient consultations (see Table B2) as of June 2022.

**Table B1.**
**Hospitals with patients on the surgical waiting list that exceed the average waiting times of 90, 120 and 180 days. June 2022**

| Hospitals | AWT | Type | Province |
|---|---|---|---|
| Virgen del Camino Hospital | 91 | Concerted | Cádiz |
| Antequera Hospital | 93 | Comarcal | Málaga |
| Virgen Macarena U.H. | 98 | Regional | Sevilla |
| Riotinto Hospital | 101 | Comarcal | Huelva |
| San Juan de Dios del Aljarafe H. | 101 | Comarcal | Sevilla |
| Lebrija H.R.H | 105 | High-resolution | Sevilla |
| Virgen del Rocío U.H. | 111 | Regional | Sevilla |
| Poniente Hospital | 112 | Comarcal | Almería |
| Reina Sofía U.H. | 112 | Regional | Córdoba |
| San Cecilio U.H. | 126 | Specialities | Granada |
| Juan Ramón Jiménez U.H. | 128 | Specialities | Huelva |
| Punta de Europa Hospital | 130 | Comarcal | Cádiz |
| Puerta del Mar U.H. | 150 | Specialities | Cádiz |
| Jaén U.H. | 176 | Specialities | Jaén |
| Virgen de las Nieves U.H. | 187 | Regional | Granada |
| Torrecárdenas U.H. | 191 | Specialities | Almería |
| Regional de Málaga U.H. | 193 | Regional | Málaga |

**Notes:** The 17 hospitals included in the table have exceed waiting times of 90 days on average, of which 8 have exceed 120 days on average and 3 have exceed 180. There are no hospitals exceeding 365 days on average. University Hospital (U.H.), Average waiting time in days (AWT), High-resolution hospital (H.R.H).

**Table B2.**
**Hospitals with patients on the waiting list for first outpatient consultations that exceed the average waiting time of 60 days. June 2022**

| Hospitals | AWT | Type | Province |
|---|---|---|---|
| La Inmaculada Hospital | 132 | Comarcal | Almería |
| Torrecárdenas U.H. | 82 | Specialities | Almería |
| Poniente Hospital | 91 | Comarcal | Almería |
| El Toyo H.R.H. | 88 | High-resolution | Almería |
| Puerta del Mar U.H. | 80 | Specialities | Cádiz |
| Punta de Europa Hospital | 125 | Comarcal | Cádiz |
| La Linea de la Concepción Hospital | 229 | Comarcal | Cádiz |
| Jérez de la Frontera U.H. | 105 | Specialities | Cádiz |
| Puerto Real U.H. | 62 | Specialities | Cádiz |
| Valle del Guadiato H.R.H. | 69 | High-resolution | Córdoba |
| Baza Hospital | 113 | Comarcal | Granada |
| San Cecilio U.H. | 126 | Specialities | Granada |
| Santa Ana Hospital | 139 | Comarcal | Granada |
| Guadix H.R.H. | 221 | High-resolution | Granada |
| Loja H.R.H. | 106 | High-resolution | Granada |
| Infanta Elena Hospital | 125 | Comarcal | Huelva |
| Juan Ramón Jiménez U.H. | 140 | Specialities | Huelva |
| Alto Guadalquivir Hospital | 228 | Comarcal | Jaén |
| Jaén U.H. | 183 | Specialities | Jaén |
| San Agustin Hospital | 148 | Comarcal | Jaén |
| San Juan de la Cruz Hospital | 141 | Comarcal | Jaén |
| La Serrania Hospital | 81 | Comarcal | Málaga |
| Regional de Málaga U.H. | 89 | Regional | Málaga |
| La Axarquia Hospital | 71 | Comarcal | Málaga |
| Virgen de la Victoria U.H. | 130 | Specialities | Málaga |
| Costa del Sol Hospital | 96 | Specialities | Málaga |
| Virgen de Valme U.H. | 107 | Specialities | Sevilla |
| Virgen Macarena U.H. | 78 | Regional | Sevilla |
| La Merced Hospital | 106 | Comarcal | Sevilla |
| San Juan de Dios del Aljarafe Hospital | 72 | Comarcal | Sevilla |
| Ecija H.R.H. | 64 | High-resolution | Sevilla |

**Note:** The 31 hospitals included in the table have exceed waiting times of 60 days on average. University Hospital (U.H.), Average waiting time in days (AWT), High-resolution hospital (H.R.H).

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Articles

# Organizaciones de apoyo: conectando redes para la innovación empresarial en clústeres de un país en desarrollo

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## Resumen:

Este artículo examina el papel de las organizaciones de apoyo (OA) en la promoción de la innovación y competitividad en empresas paraguayas. Se analizan seis clústeres importantes en el país: carnes, lácteos, cerámica y construcción, textil, farmacéuticos y químicos. Se reconstruyen las redes de colaboración utilizando datos de entrevistas a empresas y OA. Se emplean análisis de redes, regresiones econométricas y análisis cualitativo de las entrevistas. Los resultados revelan cómo las empresas acceden a recursos externos para mejorar su competitividad e innovar a través de las OA del clúster. En el entorno de un país en desarrollo, resulta fundamental la cooperación entre estas organizaciones en redes que trascienden sectores y territorios.

**Palabras clave:** Clústeres; análisis de redes sociales; desarrollo regional; organizaciones de apoyo; Paraguay.
**Clasificación JEL:** O18; O31; O32; O54; R11; R58.

## Collaboration networks, support organisations and innovation in Paraguayan clusters

## Abstract:

This article examines the role of support organizations (SOs) in promoting innovation and competitiveness in Paraguayan companies. Six important clusters in the country are analyzed: meat and derivatives, dairy, ceramics and construction, textiles, pharmaceuticals, and chemicals. Collaboration networks are reconstructed using data from interviews with companies and SOs. Network analysis, econometric regressions, and qualitative analysis of the interviews are employed. The results reveal how companies access external resources to enhance their competitiveness and foster innovation through cluster SOs. In the context of a developing country, cooperation between these organizations in cross-sector and cross-territory networks is crucial.

**Keywords:** Industrial clusters; social network analysis; regional development; support organisations; Paraguay.
**JEL Classification:** O18; O31; O32; O54; R11; R58.

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## 1. Introducción

Desde diversas corrientes de literatura, como los estudios sobre distritos industriales (Becattini, 1979), clústeres (Porter, 1990), entornos innovadores (Maillat, 1998) y nuevos espacios industriales (Saxenian, 1994), se ha señalado la importancia de las redes de cooperación entre empresas como determinantes clave del desarrollo productivo regional. En este contexto, los territorios con empresas que cooperan regularmente y mantienen vínculos externos muestran una mayor competitividad. Dicha cooperación debe darse en un entorno institucional propicio para la innovación mediante redes de actores locales (Vázquez Barquero, 2005; Saxenian, 1994).

Sin embargo, en regiones en desarrollo, como América Latina, los procesos de innovación, cooperación y competitividad presentan debilidades (Giuliani et al., 2019). En estos contextos, las redes empresariales suelen ser frágiles, por lo que el rol de las organizaciones de apoyo (OA) es fundamental. Estas OA brindan servicios que aumentan la competitividad de las empresas y promueven la cohesión de las redes locales, facilitando la difusión de conocimientos e impulsando la innovación y el desarrollo de los clústeres (Molina-Morales y Martínez-Cháfer, 2016; Galaso y Rodríguez Miranda, 2021).

Siguiendo los estudios pioneros sobre desarrollo regional y cooperación empresarial, investigaciones recientes aportan nueva evidencia sobre la importancia del contexto regional en las estrategias y colaboración empresarial en red (véase, por ejemplo, el monográfico "Clusters, Industrial Districts and Strategy" en Investigaciones Regionales (Puig & González-Loureiro, 2017)). Esto resalta la necesidad de profundizar en el estudio de los clústeres, especialmente en contextos de economías en desarrollo, donde se deben considerar especificidades que condicionan los procesos de innovación (Arocena y Sutz, 2000; Srinivas y Sutz, 2008).

En esta línea, el objetivo de este artículo es analizar las redes de colaboración en clústeres de empresas industriales paraguayas, con énfasis en el papel que cumplen las OA para la competitividad e innovación de las empresas locales. Para afrontar esta cuestión, se analizan seis clústeres de gran importancia para el desarrollo del país: cárnico, lácteo, textil, cerámica y construcción, farmacéutico, y químico. Estos seis clústeres no solo son representativos de la economía del Paraguay, sino que también comprenden una interesante diversidad en su especialización sectorial y distribución territorial.

En estos clústeres se realiza un estudio empírico a partir de una rica base de datos de encuestas a 264 empresas y entrevistas en profundidad a 15 empresas y 12 OA (Masi *et al.*, 2021). Estos datos permiten reconstruir no solo las redes de colaboración entre empresas y OA de cada clúster (redes intra-clúster), sino también una red de organizaciones que trasciende territorios y sectores (red inter-clúster). Posteriormente, se emplea una combinación de técnicas de análisis de redes, modelos econométricos y análisis cualitativo de las entrevistas para estudiar el papel de las OA en las redes y la innovación de las empresas.

Como resultado, el artículo aporta a la literatura sobre clústeres ofreciendo evidencia acerca del rol de las OA en países en desarrollo. Concretamente, se aporta evidencia sobre clústeres en Paraguay, donde apenas existen investigaciones previas de este tipo. Asimismo, el trabajo busca realizar una contribución metodológica para la literatura sobre clústeres y redes. Esta literatura se ha centrado esencialmente en estudiar redes en diferentes territorios (Fleming et al., 2007; Belso-Martínez et al., 2015; Capone et al., 2021). Algunos de estos trabajos han considerado, además de las conexiones locales, los vínculos con el exterior del territorio (Graf, 2011; Giuliani et al., 2019; Galaso y Kovářík, 2021). Sin embargo, hasta donde tenemos conocimiento, no existen estudios previos que hayan reconstruido y analizado simultáneamente redes intra-clúster y redes inter-clúster. Nuestro artículo combina ambos tipos de redes para ofrecer una evidencia más rica sobre el papel de las OA en los clústeres de países en desarrollo.

## 2. Marco conceptual

Podemos definir a un clúster como una red de empresas y organizaciones enlazadas en un sistema de valor con una cierta concentración geográfica de las actividades. La literatura sobre el tema coincide en que las redes de actores espacialmente concentrados permiten la circulación de recursos valiosos para la innovación, tales como el conocimiento, las habilidades tecnológicas o incluso las oportunidades de negocios (Saxenian, 1994).

Para estudiar empíricamente las redes de colaboración entre empresas y organizaciones, diversos trabajos han utilizado el análisis de redes sociales. Este tipo de análisis se puede llevar a cabo desde dos grandes perspectivas: individual y colectiva. En la perspectiva individual se estudia la posición de los actores (por ejemplo, personas, empresas u organizaciones) en relación con el resto de miembros de la red. La literatura se ha centrado en analizar la centralidad o prominencia de los actores, su capacidad de intermediación, la contribución a la cohesión de la red y/o el acceso a los conocimientos que fluyen en ella (Molina-Morales y Martínez-Cháfer, 2016). En esta línea, la perspectiva individual del análisis de redes ha permitido comprender la influencia de la posición en la red sobre los resultados que obtiene un actor, en particular, cómo afecta la centralidad y la intermediación de las empresas sobre sus resultados de innovación (Ahuja, 2000; Belso-Martínez et al., 2015, 2018; Boari et al. 2017; Galaso et al., 2019).

Por otro lado, la perspectiva colectiva del análisis de redes se centra en estudiar la estructura conjunta o topología de la red. Este enfoque permite analizar la evolución de un clúster o realizar comparaciones entre las redes de distintos territorios. En esta línea, algunos estudios han identificado una serie de propiedades estructurales de las redes que facilitan los procesos de innovación a escala colectiva (Fleming et al., 2007; Galaso y Kovářík, 2021; Capone et al., 2021). Estas estructuras de red contribuyen a la difusión de conocimientos y a la coordinación entre actores, por lo que se pueden considerar como una suerte de capital colectivo que pertenece a (y del que se benefician) todos los actores del territorio (Galaso, 2018).

Sin embargo, no todos los territorios tienen condiciones endógenas para formar un capital colectivo que promueva la innovación. Según Storper (1993), las estructuras sociales e institucionales del entorno local son clave para la relación entre sistemas de producción y aprendizaje en los clústeres. En países en desarrollo, los procesos de innovación se ven condicionados por la escasez socioeconómica, cognitiva y debilidad institucional (Srinivas y Sutz, 2008). La fragilidad institucional es un factor importante que limita la generación y difusión de conocimientos, así como el acceso a conocimientos externos en clústeres de países en desarrollo (Bell y Albu, 1999).

En América Latina (y, particularmente, en Paraguay), los territorios no cuentan con fuertes capacidades endógenas previas ni redes sólidas de colaboración (Maffioli et al., 2016; Crespi et al., 2014). En estos contextos, las políticas públicas desempeñan un papel clave en la construcción de un marco institucional adecuado para la innovación (Cimoli y Porcile, 2015). Estas políticas deben apuntalarse fuertemente en OA que interactúen con las empresas, contribuyendo a la construcción de redes y proporcionando servicios que aumenten la competitividad y faciliten la innovación (Watkins et al. 2015; Papaioannou et al., 2016; Jankowska et al., 2017; Galaso y Rodríguez Miranda, 2021).

Entendemos por OA a aquellas entidades, distintas de las empresas, que contribuyen al desarrollo del clúster, cooperando con las empresas y proporcionándoles servicios y/o bienes públicos que estimulan la innovación. Pueden ser actores públicos o privados, y con diversos fines (productivos, educativos, gubernamentales, etc.). La literatura ha identificado un gran número de tareas realizadas por dichos actores. Wolf et al. (2017) agrupan estas actividades en tres categorías: (1) servicios generales, (2) servicios que buscan mejorar la cooperación interna y (3) servicios que fomentan las relaciones externas. Muchos de estos actores pueden operar como OA en diferentes sectores y clústeres simultáneamente. En algunos clústeres, estas organizaciones, también conocidas como *actores colectivos*, representan una suerte de entendimiento compartido o mentalidad colectiva del territorio, porque contribuyen a dar forma a las normas, reglas y otros componentes del entorno institucional local (Hervás-Oliver, 2021).

## 2.1. El rol de las OA en las redes

Desde una perspectiva colectiva, las OA contribuyen a que la red del clúster se mantenga cohesionada. Este rol cohesionador e intermediario resulta fundamental en los procesos de innovación (Howells, 2006). La literatura de redes ha documentado cómo ciertas topologías, especialmente las relacionadas con la cohesión de la red, pueden mejorar la difusión de conocimientos (Galaso, 2018). Cuando las redes territoriales están fragmentadas en grupos de actores aislados del resto, las nuevas ideas que surgen son desconocidas para la mayoría, y la innovación se ve limitada (Fleming et al., 2007). Sin embargo, cuando la red está cohesionada en grandes componentes de actores, la difusión de conocimientos se facilita (Fleming et al., 2007; Andersson et al., 2019).

El papel cohesionador de las OA en las redes de los clústeres ha sido documentado por la literatura previa. Por ejemplo, Molina-Morales y Martínez-Cháfer (2016) mostraron cómo las OA aumentan los vínculos potenciales de las empresas al reducir la distancia entre los actores del clúster, mejorando así la proximidad y la conexión general de la red, lo que resulta especialmente valioso cuando se trata de intercambio de conocimientos tecnológicos. En esta misma línea, Galaso y Rodríguez Miranda (2021) encontraron que las OA son nodos fundamentales en la arquitectura global de las redes al evitar la fragmentación y el aislamiento de sus empresas.

Centrándose en las organizaciones públicas de investigación, Owen-Smith y Powell (2004) demostraron que la eventual desaparición de estos actores provocaría el colapso y la desintegración de la red, dejando a las empresas desconectadas. En esta línea, Graf y Henning (2009) mostraron que las organizaciones públicas de investigación ocupan posiciones significativamente más centrales que las empresas privadas en las redes regionales de innovación de Alemania. Al ocupar estas posiciones, estos actores mantienen a la red conectada, promoviendo así una cultura colectiva y un entorno innovador (Graf y Henning, 2009).

Durante las fases iniciales del clúster, la cohesión de la red depende especialmente de las OA (Owen-Smith y Powell 2004). Posteriormente, a medida que el clúster se desarrolla, las redes parecen independizarse progresivamente de estas organizaciones, mientras que las empresas privadas adquieren mayor importancia (ibid). En esta línea, estudios de clústeres en Europa parecen indicar que las OA han ido perdiendo progresivamente su capacidad para canalizar vínculos, construir redes y fomentar la interconexión entre empresas (Alberti, 2006; McDonald et al., 2006).

No obstante, en las regiones en desarrollo, donde los clústeres en general presentan menor madurez y operan en marcos institucionales más débiles, las OA son especialmente relevantes ya que facilitan el intercambio de conocimientos a escala colectiva y la creación de capacidades institucionales (Papaioannou et al. 2016). De acuerdo a estos argumentos, planteamos la siguiente hipótesis:

*H1. Las OA son clave para mantener cohesionadas las redes de los clústeres.*

## 2.2. Las OA y la innovación de las empresas

La literatura sobre redes de empresas ha mostrado que empresas centrales, bien conectadas, tienen acceso a recursos que facilitan la innovación (Ahuja, 2000). Sin embargo, en los países subdesarrollados, estos recursos que fluyen en la red pueden no ser valiosos para la innovación. Las OA podrían compensar parcialmente esta debilidad de las redes, dando acceso a conocimientos diversos y ricos, habilidades técnicas y contactos con actores externos al clúster o con recursos de la política pública. Por lo tanto, lo que resultaría especialmente valioso en contextos de subdesarrollo, más allá de la centralidad en las redes, es establecer vínculos con las OA.

Una de las principales funciones de estas organizaciones es recopilar, organizar y compartir información relevante (Howells, 2006). En este sentido, Belso-Martínez et al. (2018) encontraron que las OA desempeñan funciones de intermediación, fomentando el entendimiento mutuo entre diferentes tipos de actores para que el conocimiento pueda difundirse a través de la red. Los autores encuentran, además, que diferentes tipos de organizaciones desempeñan roles de intermediación diferentes: mientras que las universidades contribuyen particularmente a difundir conocimientos técnicos, las organizaciones privadas facilitan más la comunicación vertical y la coordinación entre empresas (Belso-Martínez et al., 2018).

De acuerdo a estos hallazgos, podemos considerar que, en los clústeres de países en desarrollo, donde la capacidad de innovación de las empresas suele ser limitada, el vínculo con OA especializadas en investigación (como universidades o centros tecnológicos) es de gran importancia para que las empresas innoven. Asimismo, el vínculo con otro tipo de OA (como asociaciones empresariales o agencias de desarrollo) puede proveer otro tipo de información particularmente valiosa en contextos de subdesarrollo, donde la debilidad institucional restringe los mecanismos de coordinación entre empresas.

Además del conocimiento, las OA brindan recursos clave como formación, transferencia tecnológica, crédito, control de calidad y promoción (Dei Ottati, 2018). En contextos de subdesarrollo, las OA son vitales para orientar, asistir y mejorar las capacidades de innovación de las empresas (Schwartz y Bar-El, 2015; Galaso y Rodríguez Miranda, 2021). Los vínculos con las OA ofrecen una red de seguridad al proporcionar consejos, rutinas y prácticas para superar las limitaciones de los clústeres de bajo rendimiento (Giuliani et al., 2019). A partir de estos argumentos, formulamos así nuestra segunda hipótesis:

*H2. Colaborar con OA incentiva la innovación de las empresas.*

### 2.3. El valor de una red inter-organizacional que trasciende al clúster

Habitualmente, las OA no se ciñen a interactuar con empresas de un solo clúster, colaboran con otras organizaciones y con empresas que operan en diferentes sectores y territorios, creando así redes que trascienden a los clústeres. Algunas OA, como por ejemplo las universidades o los centros de investigación, pueden desempeñar un papel fundamental, introduciendo conocimientos externos en el clúster. Los flujos de conocimiento externo son esenciales para la innovación, ya que proporcionan nuevas ideas y soluciones tecnológicas que mejoran la competitividad (Breschi y Lenzi, 2016). También evitan situaciones de bloqueo en las que el conocimiento que circula a escala local es redundante (Boschma, 2005). En los clústeres de países en desarrollo, la apertura a los conocimientos externos y su posterior difusión a escala local son particularmente relevantes para la innovación (Bell y Albu, 1999).

En este sentido, la literatura ha estudiado los denominados *gatekeepers*, es decir, aquellos actores que están fuertemente conectados con la red local y, simultáneamente, con las redes globales de innovación. Esta doble conexión, local y externa, hace que los gatekeepers jueguen un papel fundamental en la introducción y difusión de nuevos conocimientos. Aunque algunas investigaciones han constatado que los gatekeepers tienden a ser las grandes empresas (Morrison, 2008), otros estudios demuestran que las OA desempeñan este papel con más frecuencia que las compañías privadas (Graf, 2011). En los clústeres de países en desarrollo, las empresas locales suelen estar más desconectadas de las redes globales de innovación, lo cual limita su acceso a conocimientos externos y, por ello, cabe esperar que el rol de gatekeeper recaiga más en las OA. Al cumplir este rol, estas organizaciones ayudan a reducir los costos asociados al acceso a fuentes externas de conocimientos, así como a experiencias especializadas y valiosas para los procesos de innovación (Molina-Morales y Martínez-Cháfer, 2016).

Este tipo de intermediación supone un recurso especialmente útil para las empresas del clúster, porque permite poner en contacto actores que afrontan problemas diversos y manejan conocimientos variados. Como plantea Hervás-Oliver (2021), estas organizaciones no solo son capaces de acceder a conocimientos externos sino también de adaptarlos a las especificidades del territorio y, para ello, cuentan con el apoyo de organizaciones de otras industrias. Es decir, su conexión con una red que trasciende al clúster otorga a las OA una visión amplia de los problemas que pueden afrontar las empresas con las que colaboran.

De esta forma, las empresas del clúster, al conectarse con las OA, acceden a un set de herramientas, información y activos que surgen del contacto que tienen esas organizaciones en distintos niveles sectoriales y territoriales. En otras palabras, las OA conforman redes de colaboración inter-organizacional que operan en diferentes planos sectoriales y territoriales, lo que permite vincular a las empresas con valiosos recursos y conocimientos de fuentes externas al clúster. De acuerdo a estos argumentos, podemos plantear nuestra tercera hipótesis del siguiente modo:

*H3. Las OA integran redes que trascienden al clúster, lo que permite a las empresas acceder a recursos y conocimientos valiosos para su innovación.*

## 3. Metodología y datos

El estudio empírico emplea datos primarios que surgen de entrevistas a empresas y organizaciones que operan en seis clústeres de Paraguay. La selección de clústeres objeto de estudio se basa en investigaciones previas sobre la especialización productiva y el desarrollo territorial en Paraguay (Servín y Masi, 2018). En particular, seguimos tres criterios de selección: (1) aglomeración espacial de empresas en un sector, (2) relevancia económica del sector a escala regional y nacional, y (3) posibles vínculos de cooperación horizontal (es decir, se descartaron sectores dominados por pocas empresas de gran tamaño). Como resultado, los seis casos seleccionados son los siguientes:

- *Dos agroindustrias alimentarias*: el clúster cárnico (localizado en Asunción, Departamento Central, Itapúa y Boquerón); y el clúster lácteo (en el Departamento Central, Caaguazú, Boquerón e Itapúa).
- *Dos casos de paradigma tecnológico maduro e intensivos en mano de obra*: el textil (concentrado en los departamentos Central y Ñeembucú); y el de la cerámica y construcción (Central, Cordillera e Itapúa).
- *Dos industrias más intensivas en tecnología y capital*: los clústeres farmacéutico y químico, ambos concentrados en el distrito de Asunción y el Departamento Central.

Estos clústeres presentan diversidad sectorial y geográfica, incluyendo casos de alta concentración espacial y otros más dispersos por el territorio. Además, representan en forma bastante equilibrada casos relevantes dentro de la estructura productiva de la economía paraguaya.

Los datos primarios se obtuvieron en dos trabajos de campo. En el primero, realizado entre noviembre de 2016 y marzo de 2017, se aplicaron entrevistas semiestructuradas presenciales y telefónicas a 264 directores (gerentes o dueños) de empresas en los seis clústeres seleccionados. La tasa de respuesta en el trabajo de campo (que es, a su vez, la cobertura del universo de empresas en cada clúster) fue del 62% para el clúster de la carne, 69% en el farmacéutico, 76% en el lácteo, 86% en el de la cerámica y construcción, 73% en el clúster químico y 87% en el textil (para más información sobre este trabajo de campo, ver Servín y Masi, 2019).

En las entrevistas, se obtuvo información sobre las empresas, como año de fundación, empleados, actividades principales, exportaciones. También se recopiló información detallada de las actividades de innovación de acuerdo al manual de Oslo (OCDE/Eurostat 2005). También se indagó sobre los vínculos de colaboración con otras empresas y OA. Para los vínculos empresa-empresa, se recopiló información sobre diversas actividades de colaboración, como marketing, transporte, compras conjuntas y programas de exportación. En cuanto a los vínculos empresa-organización, se consultó sobre colaboraciones para mejorar la competitividad, sin especificar el tipo de colaboración. Estos datos permiten reconstruir las redes de colaboración en los clústeres. Dadas las elevadas tasas de respuesta, el diseño del trabajo de campo y la forma de establecer los vínculos entre nodos (cuando al menos uno de ellos declara colaborar), nuestros datos permiten inferir estimaciones adecuadas de las redes sin cubrir a toda la población de nodos (Smith et al., 2017).

El segundo trabajo de campo se realizó en el segundo semestre de 2020. Se llevaron a cabo entrevistas en profundidad con directores y gerentes de 12 OA y 15 empresas de los seis clústeres estudiados. De forma intencional, se seleccionaron para entrevistar en profundidad a las organizaciones y empresas más centrales en las redes de los clústeres que resultan del primer trabajo de campo, combinando, para ello, índices de centralidad de grado y de vector propio. Esto permitió estudiar a las empresas y organizaciones mejor conectadas y con mayor influencia y relevancia en sus respectivos clústeres. Las entrevistas proporcionaron información cualitativa sobre los procesos de innovación de las empresas y el papel de las redes y las OA. También se recopiló información sobre los vínculos de colaboración entre las OA, lo que permitió reconstruir la red que conecta a las OA de diferentes clústeres. Estos vínculos representan diversas formas de colaboración inter-organizacional para promover la competitividad de las empresas. (Ver Masi *et al.*, 2021, para más información sobre este trabajo de campo.)

Para contrastar la H1 se reconstruyen y analizan las redes de los clústeres. Se elabora una red para cada clúster, considerando a las empresas y OA como nodos, y se establece un vínculo (no dirigido) entre dos nodos cuando al menos uno de los dos actores declara que existe colaboración entre ellos. Posteriormente, se simula cómo afectaría a la estructura de la red de cada clúster la eliminación de las OA. Para ello, se calculan tres indicadores de cohesión: grado medio, porcentaje de nodos aislados y tamaño del componente principal.[1] A continuación, se eliminan a las OA de las redes (manteniendo a las empresas) y se vuelven a calcular los mismos indicadores. De acuerdo a la H1, se espera que las OA cumplan un rol central y su eliminación perjudicaría la cohesión de las redes. Esto se reflejaría en una disminución del grado medio y del tamaño del componente principal, y un aumento de los nodos aislados.

Para contrastar la H2 se utilizan modelos de regresión logística que estiman la influencia de la colaboración con las OA en la innovación de las empresas. Como variables dependientes se utilizan tres variables binarias que miden si la empresa entrevistada realiza o no cada una de las siguientes actividades de innovación: (1) I+D, (2) compra de maquinaria y equipos, (2) compra de licencias y/o consultorías. La variable dependiente es la cantidad de vínculos de colaboración que mantiene la empresa con OA. Además, los modelos incluyen las siguientes variables de control: el tamaño de la empresa (medido por el número de empleados), el porcentaje de las ventas que se dirige a la exportación, y la cantidad de vínculos de colaboración que mantiene la empresa con otras compañías del clúster. Asimismo, para controlar por diferencias en los niveles de innovación asociadas al sector, los modelos incluyen variables dicotómicas que identifican el tipo de actividad económica de la empresa, diferenciando entre agroindustria, sectores más intensivos en tecnología y sectores tradicionales. Otras variables fueron utilizadas, como el año de inicio de actividades de la empresa, origen del capital, y la proporción de profesionales en la plantilla, pero no arrojaron significación en las estimaciones, por lo que se descartaron.

Se realizan las estimaciones con el método de estimación robusta de los errores por conglomerados, que asume que las observaciones son independientes entre sí, salvo las que pertenecen a un mismo clúster, reconociendo esa posible interdependencia y tratándola en la estimación de los residuos. A su vez, para controlar la calidad de los modelos, se realizan test de bondad de ajuste y se observa que presentan tasas de predicción y valores ROC adecuados.

Finalmente, para contrastar la H3 se reconstruye y analiza la red que surge de los vínculos entre organizaciones de diferentes clústeres. Para la elaboración de esta red, se consideran como nodos a las OA más centrales de cada clúster y se establece un vínculo entre ellas cuando al menos una ha declarado mantener una relación de colaboración con otra. Para estudiar el rol de las OA como intermediarios entre clústeres, se calculan los estadísticos de intermediación de Gould y Fernández (1989). De acuerdo a estos autores, un intermediario es un nodo que conecta a otros dos nodos desconectados entre sí, y esto puede ser dentro del mismo grupo de nodos o entre grupos diferentes. En nuestro caso, los grupos son los clústeres a los que pertenecen las OA. Las OA pueden tener diferentes roles según intermedien entre otras OA del mismo clúster o de diferentes clústeres. El método de Gould y Fernández (1989) utiliza inferencia estadística para identificar actores con posiciones de intermediación y determinar si se debe a una distribución aleatoria de relaciones o a una estructura social subyacente.

De acuerdo a la H3, se espera que esta red inter-organizacional logre conectar a OA que operan en distintos sectores y territorios y se espera poder identificar a algunas organizaciones que cumplen roles clave como intermediarios entre clústeres. Complementamos el análisis de redes con un estudio de la información cualitativa recabada en las entrevistas en profundidad a empresas y organizaciones. Esta información permite indagar sobre las prácticas de las OA y cómo, a través de la cooperación en redes inter-clúster, se promueve la competitividad y la innovación en las empresas.

1 El grado medio es el número medio de enlaces adyacentes a cada nodo; la proporción de nodos aislados es el porcentaje de nodos sin enlaces; un componente conectado es un grupo de nodos que está -directa o indirectamente- conectado entre sí y desconectado del resto de la red, el componente principal es aquél que conecta más nodos.

# 4. Resultados

## 4.1. Características de los clústeres analizados

Los clústeres de industrias intensivas en tecnología y capital (farmacéutico y químico) tienen empresas grandes (promedio de 150 empleados en el farmacéutico y 278 en el químico). Son industrias mayormente de capitales nacionales, con enfoque en el mercado interno y la exportación. El personal altamente calificado es más relevante en el sector farmacéutico (alrededor del 40% de la plantilla) y algo menos en el químico (menos de un tercio).

En los clústeres agroalimentarios (cárnico y lácteo), el cárnico tiene empresas más grandes (promedio de 278 empleados), mientras que el lácteo tiene un tamaño mediano a grande (promedio de 150 empleados) con presencia de empresas pequeñas. También son principalmente de capitales nacionales y tienen orientación tanto al mercado interno como al externo. En el sector cárnico, la exportación es el mercado principal, mientras que en el lácteo el mercado externo tiene menos peso. Ambas industrias tienen porcentajes similares de personal altamente calificado, en torno al 20% de la plantilla.

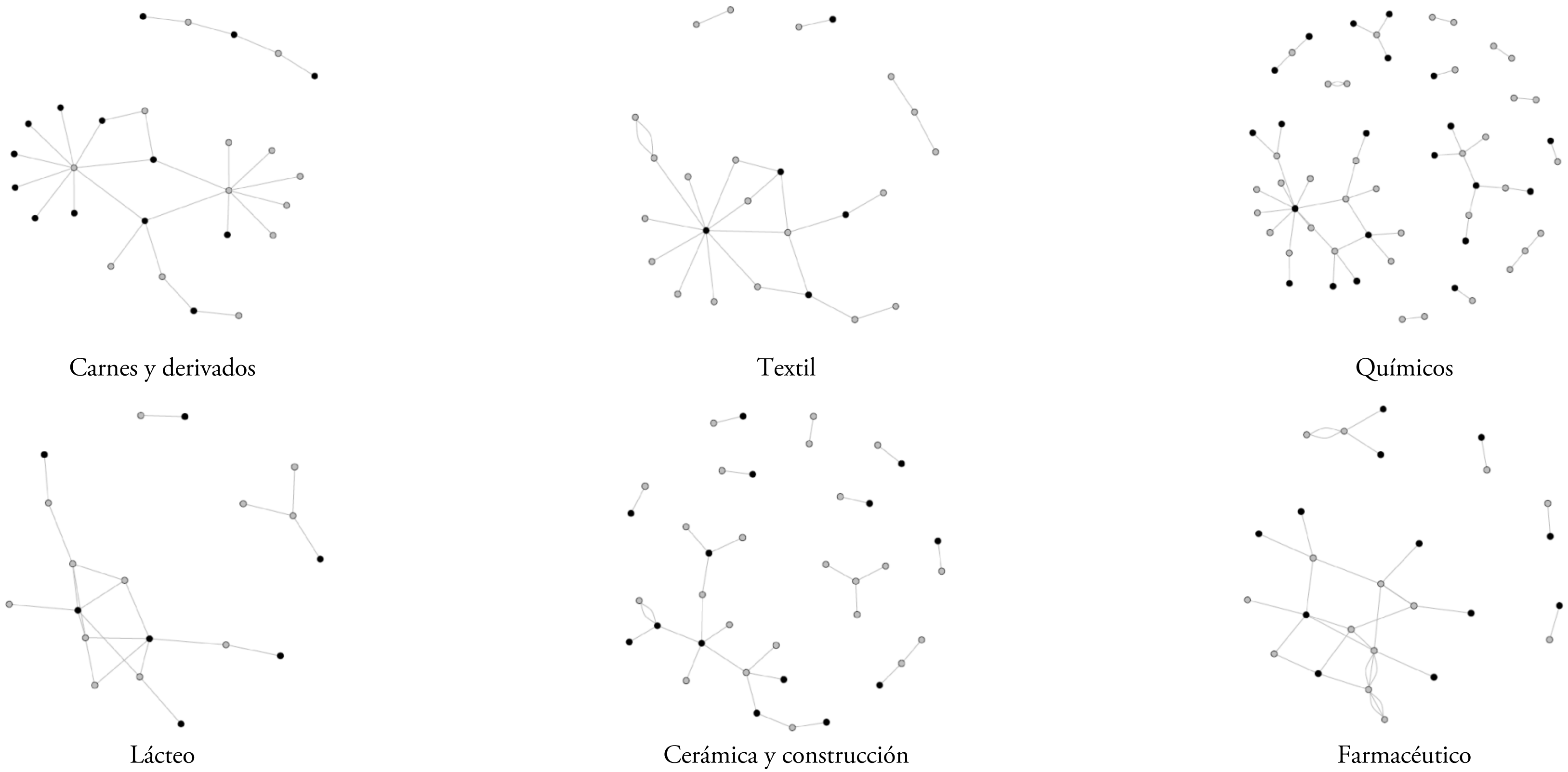
En las industrias maduras e intensivas en mano de obra (cerámica, construcción y textil), las empresas son de tamaño pequeño y mediano (promedio de 19 empleados en cerámica y construcción, y 54 empleados en textil). Los clústeres están compuestos por empresas de capitales nacionales, con enfoque en el mercado interno. También presentan un bajo porcentaje de personal altamente cualificado, un 10% y 13% de la plantilla en cerámica y textil respectivamente.

En cuanto a la cooperación, los clústeres farmacéutico, cárnico y lácteo son los que muestran una mayor colaboración entre empresas y OA. En el caso de la carne, la cooperación se da principalmente entre empresas y organizaciones. Estos tres sectores también muestran un mayor comportamiento innovador en general: un 71%, 87% y 77% de las empresas del clúster farmacéutico, cárnico y lácteo respectivamente, realizan actividades de innovación. Sin embargo, existen diferencias entre clústeres. Aunque la adquisición de maquinaria es la forma más común de innovación en todos ellos (entre el 55% y el 78% de las empresas), en carne y farmacéutico también se realiza I+D en un tercio de las empresas, mientras que en lácteo solo lo hace un 15%. Por otro lado, los clústeres de cerámica, textil y químico muestran una menor cooperación entre los actores. En cerámica y textil, esto se refleja en resultados más pobres en términos de innovación, con solo un 24% y un 48% de las empresas respectivamente que innovan. Sin embargo, el clúster químico muestra un comportamiento más innovador, con un 81% de las empresas que llevan a cabo alguna actividad innovadora.

## 4.2. Contraste de las hipótesis de investigación

En la Figura 1 se presentan las redes de cooperación en los seis clústeres. La Tabla 1 muestra indicadores que describen la estructura de las redes comparando la cohesión de la red con y sin las OA. Estos ejercicios confirman la H1 acerca de la importancia de las OA para mantener cohesionadas las redes de los clústeres. En la Figura 1 se observa cómo las organizaciones ocupan posiciones centrales. Si se eliminan, las redes se fragmentarían y muchas empresas quedarían aisladas. Esto se corrobora en la Tabla 1: al eliminar las organizaciones, el grado medio disminuye, el componente principal de la red pierde peso y muchos nodos quedan aislados. Según la literatura, esta fragmentación dificulta la circulación de conocimientos y la coordinación entre actores, lo que afecta negativamente la innovación del clúster.

FIGURA 1.
**Redes de colaboración en los clústeres estudiados**




**Nota:** los nodos grises son empresas, los nodos negros organizaciones, y los vínculos las relaciones de cooperación.
**Fuente:** elaboración propia.

**Tabla 1.**
**Principales indicadores de las redes en los clústeres estudiados**

| Clúster | Nº nodos | | Grado medio | | Componente principal de la red (en % del total de nodos) | | Nodos aislados (en % del total de nodos) | |
|---|---|---|---|---|---|---|---|---|
| | Empresas | Organizaciones | Red con organizaciones | Red sin organizaciones | Red con organizaciones | Red sin organizaciones | Red con organizaciones | Red sin organizaciones |
| Textiles | 20 | 5 | 1.0 | 0.3 | 74% | 15% | 0% | 55% |
| Productos químicos | 36 | 21 | 0.8 | 0.3 | 39% | 8% | 0% | 50% |
| Farmacéutico | 14 | 12 | 1.2 | 1.04 | 62% | 50% | 0% | 36% |
| Cerámica/construcción | 23 | 14 | 0.8 | 0.3 | 43% | 17% | 0% | 57% |
| Lácteos | 12 | 7 | 1.1 | 0.9 | 68% | 42% | 0% | 33% |
| Carnes y derivados | 13 | 14 | 1.0 | 0.4 | 81% | 43% | 0% | 54% |

**Fuente:** elaboración propia.

Para contrastar la H2, se estiman modelos econométricos logísticos donde se busca probar si la vinculación con OA se asocia con una mayor probabilidad de innovar. En la Tabla 2 se presentan los resultados de estos modelos para los tres tipos de actividad de innovación analizados.

**Tabla 2.**
**Determinantes de la innovación según el tipo de actividad innovadora**

| Variables | I+D dy/dx | Compra de maquinaria y equipo dy/dx | Licencias y/o consultorías dy/dx |
|---|---|---|---|
| Cooperación con OA | 0,0387** | 0,1269*** | 0,0069 |
| Tamaño | 0,1128*** | 0,2295*** | 0,0957** |
| % exportación | 0,0010 | 0,0018 | 0,0030*** |
| Cooperación con empresas | 0,0342** | -0,0004 | 0,0494*** |
| Sector complejo | 0,0845* | 0,1808*** | 0,1519*** |
| Agroindustria | 0,0293* | 0,1769*** | 0,1557 |
| *N° observaciones* | *246* | *246* | *246* |
| *Curva ROC* | *0,8966* | *0,7625* | *0,8152* |
| *Test de bondad de ajuste (1%)* | *no rechaza* | *no rechaza* | *no rechaza* |
| *Tasa de acierto de valor positivo (innova)* | *72,22%* | *75,00%* | *56,52%* |
| *Tasa de acierto valor negativo (no innova)* | *92,28%* | *70,65%* | *83,82%* |

**Nota:** Modelo Logit. Estimación robusta de los errores estándar por conglomerados. * nivel de significación al 10%, ** Nivel de significación al 5% y *** Nivel de significación al 1%.
**Fuente:** elaboración propia en base a datos de encuesta propia a empresas.

La tabla muestra los efectos marginales (dy/dx) para observar el impacto de un aumento en la variable explicativa sobre la probabilidad de innovación empresarial. Por ejemplo, para la realización de I+D, un aumento en el tamaño de la empresa incrementa en un 11,3% la probabilidad de realizar actividades de I+D. Además, aumentar la cooperación con otras empresas y OA incrementa entre 3% y 4% la probabilidad de innovar en I+D. Estos resultados concuerdan con estudios empíricos que destacan la importancia de las redes de colaboración en la innovación empresarial (por ejemplo, Ahuja, 2000; Galaso et al., 2019).

Respecto a las variables de control, los resultados muestran que el tamaño de la firma es crucial para explicar la innovación. La orientación exportadora tiene un efecto menor en la innovación por licencias o consultorías. Otro de los controles que resulta significativo refiere a las diferencias sectoriales. En los sectores más complejos (farmacéutico y químico) se observa mayor tendencia a innovar que en los sectores tecnológicamente maduros. En la agroindustria destaca la innovación en equipos, en línea con las entrevistas que revelan el predominio de importación de maquinaria. En el sector químico y farmacéutico, además de la actualización de equipamiento, se destaca la práctica de compra de licencias y contratación de consultorías para innovar.

Los modelos confirman la importancia de los vínculos con OA para la innovación empresarial, respaldando la H2. Es crucial formar redes de cooperación empresarial y colaborar con OA para la innovación en I+D. Para la innovación a través de la adquisición de maquinaria y equipos, la vinculación con OA es relevante, mientras que la cooperación con otras empresas no es significativa. En el caso de la innovación mediante licencias y consultorías, son relevantes los vínculos con empresas, mientras que la vinculación con OA no es significativa.

Finalmente, para contrastar la H3, se construye una red de colaboración entre las OA y se calcula el rol de intermediario de estas organizaciones. Asimismo, se analiza la información cualitativa extraída de las entrevistas en profundidad. Como se hará referencia a diferentes OA a través de sus siglas, en la Tabla 3 se listan las principales OA.

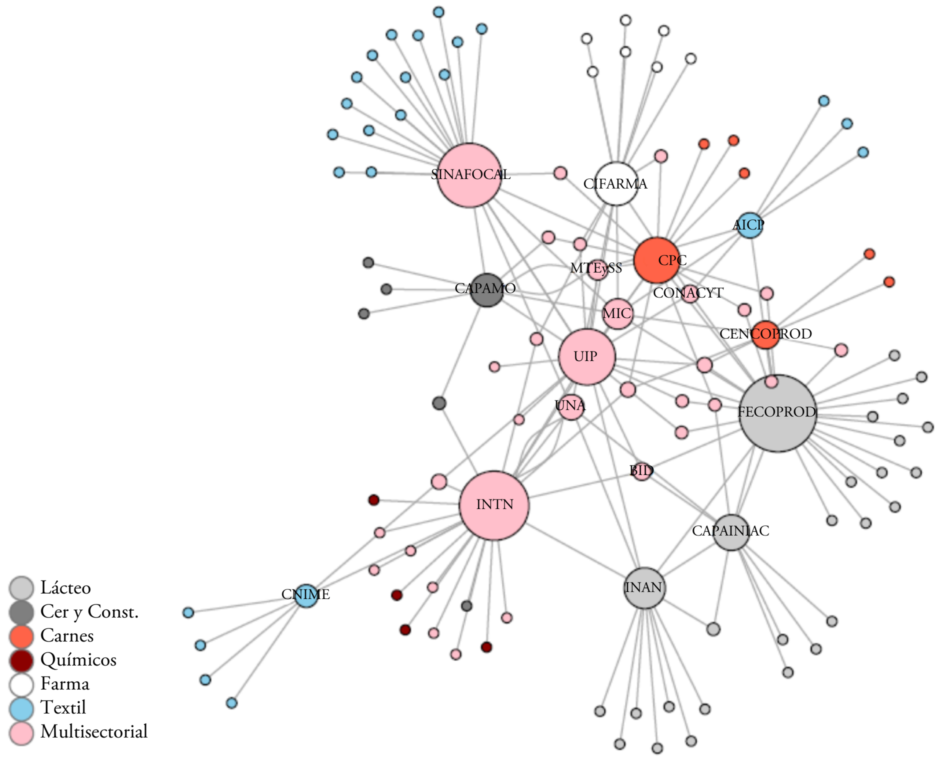
Tabla 3.
**Principales OA**

| OA relacionadas con la política pública | OA privadas o académicas |
|---|---|
| APC: Asociación Paraguaya para la Calidad | AICP: Asociación de Industriales Confeccionistas del Paraguay |
| CICLA: Comisión Interinstitucional de Competitividad Láctea | APROLE: Asociación de Productores de Leche |
| CNIME: Consejo Nacional de Industrias Maquiladoras de Exportación | CAPACO: Cámara Paraguaya de la Industria de la Construcción |
| CONACYT: Consejo Nacional de Ciencia y Tecnología. | CAPADEI: Cámara de Desarrollo Inmobiliario |
| DINAPI: Dirección Nacional de Propiedad Intelectual | CAPAINLAC: Cámara Paraguaya de Industrias Lácteas |
| DINAVISA: Dirección Nacional de Vigilancia Sanitaria | CAPAMO: Cámara Paraguaya de Mosaicos |
| DNA: Dirección Nacional de Aduanas | CEMAP: Cámara Empresas Maquiladoras Paraguaya |
| INAN: Instituto Nacional de Alimentación y Nutrición | CENCOPROD: Central de Cooperativas de Producción (planta procesadora de cuero) |
| INTN: Instituto Nacional de Tecnología, Normalización y Metrología | CIFARMA: Cámara de la Industria Farmacéutica |
| MADES: Ministerio de Ambiente y Desarrollo Sostenible | CPC: Cámara Paraguay de Carnes |
| MIC: Ministerio de Industria y Comercio | CPIP: Cámara Paraguaya de la Industria del Plástico |
| MRE: Ministerio de Relaciones Exteriores | FECOPROD: Federación de Cooperativas de Producción |
| MTEySS: Ministerio de Trabajo y Seguridad Social | FEDEMIPYME: Federación Paraguaya de Micro, Pequeñas y Medianas Empresas |
| REDIEX: Red de Inversiones y Exportaciones | FEPRINCO: Federación de la Producción Industria y el Comercio |
| SENACSA: Servicio Nacional de Calidad y Salud Animal | UGP: Unión de Gremios del Paraguay |
| SINAFOCAL: Sistema Nacional de Formación y Capacitación Laboral | UIP: Unión de Industrias del Paraguay |
| SNPP: Servicio Nacional de Promoción Profesional | UNA: Universidad Nacional de Asunción |

**Fuente:** elaboración propia.

La Figura 2 muestra la red inter-sectorial de OA, formada por 108 organizaciones y 158 vínculos. En promedio, cada organización tiene 2,93 vínculos. Los nodos más centrales son FECOPROD, INTN, SINAFOCAL y UIP. Esta última destaca por colaborar con cámaras, organizaciones sectoriales, entidades públicas e internacionales. Para apoyar la competitividad de la industria, UIP ofrece un Instituto Técnico de Formación, un Centro de Productividad y Calidad y un Centro de Innovación. También destacan las gremiales FEPRINCO, FEDEMIPYME y UGP.

Figura 2.
**Red de colaboración inter-sectorial entre OA**




**Fuente:** elaboración propia.

Los roles de intermediación entre clústeres desempeñados por OA se resumen en la Tabla 4. El análisis revela el papel crucial de la UIP, FECOPROD y, en menor medida, SINAFOCAL. La UIP, al ser multisectorial y desempeñar como *gatekeeper*, facilita la transferencia de conocimientos entre diferentes clústeres. FECORPOD, CAPAINLAC e INAN también ejercen la función de *gatekeeper*, intermediando entre organizaciones de sus respectivos clústeres y otros sectores. En el clúster cárnico, CPC actúa como *liaison*, intermediando entre organizaciones de diferentes clústeres. INTN y, especialmente, SINAFOCAL también cumplen este rol gracias a su carácter multisectorial. Este tipo de intermediación favorece el acceso y difusión de conocimientos variados entre territorios y sectores, brindando un valioso respaldo a las empresas de las industrias interconectadas.

Complementando los análisis anteriores, las entrevistas permitan profundizar en cómo esta red inter-sectorial de OA genera efectos positivos en las empresas. La Tabla 5 resume las iniciativas y actividades impulsadas por OA en cada clúster. En particular, se analiza cómo colaboran las OA en redes inter-clúster y cómo esto facilita a las empresas el acceso a recursos que respaldan los procesos de innovación.

**Tabla 4.**
**Roles de intermediación de las OA**

| Organización | *Coordinator* | *Itinerant* | *Gatekeeper* | *Liaison* | Total |
|---|---|---|---|---|---|
| UIP | 19 | 0 | 41 | 3 | 63 |
| FECOPROD | 12 | 4 | 37 | 8 | 61 |
| SINAFOCAL | 2 | 0 | 18 | 30 | 50 |
| INTN | 0 | 0 | 13 | 7 | 20 |
| CAPAINLAC | 9 | 0 | 6 | 0 | 15 |
| CPC | 0 | 0 | 3 | 8 | 11 |
| INAN | 0 | 0 | 10 | 0 | 10 |
| CENCOPROD | 0 | 0 | 2 | 1 | 3 |

**Nota:** el rol de *coordinator* implica intermediar entre dos organizaciones del mismo clúster que el de la organización intermediaria, *itinerant* supone intermediar entre dos organizaciones que pertenecen a un mismo clúster pero que es distinto del clúster del intermediario, el rol de *gatekeeper* implica intermediar entre una organización de su mismo clúster y otra de un clúster diferente, *liason* supone intermediar entre dos organizaciones de clústeres diferentes, ambos distintos al clúster del intermediario, la columna *total* recoge la suma de los roles de intermediación desempeñados por cada organización.

**Fuente:** elaboración propia a partir de los roles propuestos por Gould y Fernández (1989).

**Tabla 5.**
**Principales hallazgos de las entrevistas sobre el rol de las OA**

| Iniciativa del clúster | Cooperación con OA inter-sectoriales | Acceso a recursos/beneficios para las firmas |
|---|---|---|
| **Clúster Lácteo** | | |
| Comisión Interinstitucional CICLA, en la que participan organizaciones públicas y privadas. | Las OA del sector CAPAINLAC y APROLE se vinculan con: i) MRE y REDIEX; ii) otras OA privadas como FECOPROD y UIP; iii) ministerios públicos y OA como SENACSA, INAN, INTN. | Implementación de un Plan Nacional de Desarrollo Sostenible de la Cadena de Lácteos. Es una red de acceso a recursos asociados a apoyos de la política pública, aspectos sanitarios y tecnológicos, aspectos de calidad, apoyo a la inserción internacional del sector. |
| Accionar de CAPAINLAC como cámara que agrupa a las principales industrias del clúster | Colaboración bilateral de CAPAINLAC con: i) Federación Panamericana de la Leche y a través de ella con FAO y BID; ii) SNPP; iii) universidades privadas y UNA (área de ciencias químicas, veterinaria, etc.) | Acceso a investigación sobre producto y tecnología, apoyo en negociaciones comerciales y apertura de mercados, formación profesional, aspectos de calidad. |
| Agrupación de cooperativas lácteas a FECOPROD | FECOPROD permite vincular a las cooperativas lácteas con iniciativas y cooperativas de otros clústeres, Ministerios y OA del sector público, organismos internacionales (BID, UE, USAID, JICA, Confederación Alemana de Cooperativas, INTA de Argentina). | Acceso a programas públicos de apoyo, tecnología y conocimiento internacional sobre el sector, cooperación internacional, cooperación con cooperativas de otros sectores productivos. |

**Tabla 5.** cont.
**Principales hallazgos de las entrevistas sobre el rol de las OA**

| Iniciativa del clúster | Cooperación con OA inter-sectoriales | Acceso a recursos/beneficios para las firmas |
|---|---|---|
| **Clúster Cárnico** | | |
| CENCOPROD (central cooperativa) | Articulación con FECOPROD, UIP, Ministerio de Industria, Ministerio de Ambiente, Ministerio de Ganadería y SENACSA. | Alianza entre cooperativas del clúster para lograr economía de escala creando una industria del cuero y subproductos (cebo, harina) propiedad de las cooperativas. |
| Mesas técnicas con OA públicas y rol articulador de la CPC con OA públicas y privadas. | Articulación con Ministerio de Ambiente, Ministerio de Ganadería, REDIEX, SENACSA, SINAFOCAL, SNPP, UIP, UGP y universidades (área veterinaria, ciencias agrarias). | Convenios y acuerdos de cooperación para apoyo en mejora de calidad, realización de investigaciones, buscar soluciones a aspectos normativos y ambientales, apoyo en inserción internacional y mercados. |
| **Clúster farmacéutico** | | |
| Mesa del sector químico farmacéutico con RIEDEX y proyectos CONACYT. | Rol de CIFARMA para vincular empresas con REDIEX y CONACYT. | Acceso a proyectos y recursos de CONACYT (para innovar) y RIEDEX (para acceso a mercados e inversiones). |
| Rol de CIFARMA para representar intereses de las empresas y articular con otras OA. | Articulación entre empresas y la DINAPI y DINAVISA. Vinculación con la Asociación Latinoamericana de Industrias Farmacéuticas. Relación con UIP y FEPRINCO. | Defensa de intereses de las empresas en aspectos normativos, sanitarios y acceso a mercados. |
| Internacionalización de empresas del sector en base a recursos propios | Algunas empresas se relacionan con multinacionales en otros países y/o universidades del exterior sin necesidad de intermediación de OA. | Acceso a mercados externos y tecnología. |
| **Clúster cerámica y construcción** | | |
| Cámara Paraguaya del Hormigón Elaborado, CAPAMO, CAPACO y CADEI. | Las cámaras articulan intereses gremiales de las empresas y se vinculan con otras cámaras como la UIP, pero, sobre todo, se vinculan con organismos públicos y de gobierno (Ministerio de Obras Públicas, otros ministerios y gobiernos locales). | Sobre todo, hay una aportación de las cámaras en los temas normativos y marcos regulatorios, impulsando mejoras, junto con las OA públicas. |
| **Clúster químico** | | |
| Cámara Paraguaya de la Industria del Plástico. | Se interactúa con la UIP y el Centro de Importadores Paraguayo, con OA públicas como APC, INTN o SNPP. | Apoyo en la defensa de intereses del sector, aspectos arancelarios y normativos, aspectos de calidad, difusión de información relevante para el sector. |
| Vinculaciones entre empresas y universidad. | Universidades privadas y la UNA. | Se colabora mediante proyectos, extensión universitaria y uso de servicios de laboratorios. |

**TABLA 5.** CONT.
**Principales hallazgos de las entrevistas sobre el rol de las OA**

| Iniciativa del clúster | Cooperación con OA inter-sectoriales | Acceso a recursos/beneficios para las firmas |
|---|---|---|
| **Clúster textil** | | |
| Actividades impulsadas por la Asociación de Industriales Confeccionistas del Paraguay. | Se trabaja con SINAFOCAL, Ministerio de Industria y Comercio, Ministerio de MIPYMES, REDIEX, SNPP, UIP, centros de formación y tecnológicos, universidades y el CONACYT. | Actividades de promoción comercial, formación de trabajadores, apoyo a la exportación y a la cooperación internacional (Unión Europea y Taiwán). Vinculación con redes internacionales (Inexmoda Colombia, SENAI de Brasil, SENA de Colombia, Milano Fashion Institute). Intermediación para lograr apoyos gubernamentales para la producción de textiles. Articulación de producción nacional para el Ministerio de Salud durante pandemia COVID-19. |
| CEMAP (rubro confección y calzado). | Relacionamientos de CEMAP con CNIME, Aduana, Ministerio de Hacienda y el INTN. | Rol regulador del CNIME que se encarga de recibir y verificar las solicitudes de operar bajo el régimen de maquila (en este caso para confección y calzado). Cooperación entre OA para capacitación y promoción y financiamiento de la exportación, adecuación tecnológica y de infraestructura. |

**Fuente:** elaboración propia.

Este análisis destaca el rol activo de las cámaras empresariales en los clústeres farmacéutico, lácteo, cárnico y textil. Además de los aspectos gremiales, estas cámaras impulsan iniciativas para el desarrollo productivo, la innovación y el acceso a mercados. Establecen vínculos con otras OA públicas y privadas, nacionales e internacionales, así como con universidades. En el clúster químico y el de cerámica y construcción, el papel de las cámaras está más limitado a aspectos gremiales y normativos. No obstante, en el sector químico se registra cooperación entre universidades y empresas para el desarrollo de productos y servicios técnicos.

En general, las entrevistas confirman los resultados del análisis de redes: la baja cooperación entre empresas y el rol cohesionador de las OA, que vinculan empresas con recursos y entre sí. Las cámaras empresariales desempeñan un papel de interacción entre empresas y OA públicas, tanto en fomento productivo como en innovación y regulación. Las universidades y CONACYT son relevantes en la innovación y vinculación con empresas en la mayoría de los clústeres. En suma, a partir del análisis de la red inter-organizacional y de la evidencia que surge de las entrevistas, se corrobora nuestra tercera hipótesis acerca de la red inter-clúster como fuente de recursos valiosos para la innovación de las empresas.

## 5. Conclusiones

En esta investigación se aporta evidencia relevante para comprender cómo, en un país en desarrollo y frente a una escasa cooperación inter-empresarial, las empresas acceden a recursos externos para innovar y mejorar su competitividad a través de las OA y, fundamentalmente, gracias a la cooperación de estas organizaciones en redes que trascienden a sectores y territorios.

Este artículo respalda la literatura previa acerca del papel crucial de las OA en la cohesión de redes de clústeres y la promoción de la innovación empresarial. Además, aporta evidencia empírica novedosa sobre cómo las OA desempeñan dicho papel: una red inter-organizacional, que trasciende a los diferentes clústeres, logra conectar recursos de la política pública y centros de conocimiento con las diferentes industrias y territorios. Esto facilita la difusión de conocimientos y pone a disposición de las firmas un conjunto de recursos de gran valor para sus procesos de innovación.

Estos resultados plantean diversas vías para mejorar la comprensión del fenómeno. El estudio revela que los clústeres no son homogéneos, sino que presentan diferencias sectoriales, territoriales, institucionales y organizativas. Además, se destaca el enfoque sectorial de las políticas nacionales de apoyo productivo en la economía paraguaya. Para futuras investigaciones, sería interesante profundizar en el estudio de cada clúster.

La evidencia sobre el rol de las OA en la canalización de los apoyos de la política pública a los clústeres abre una nueva línea de investigación: cómo fomentar alianzas público-privadas aprovechando la presencia activa de OA a pesar de la falta de cultura de cooperación entre las empresas. Esta limitación podría obstaculizar el papel de las OA en la promoción de la cooperación e innovación en los clústeres.

Finalmente, en términos de diseño de políticas públicas, los hallazgos del artículo indican que la intermediación a través de organizaciones que abarcan diversos clústeres puede facilitar la implementación efectiva de políticas a escala nacional. Por lo tanto, es recomendable que las políticas nacionales incluyan mecanismos que fomenten la creación y fortalecimiento de una red inter-sectorial e inter-territorial de OA. Esto sería un activo valioso para fomentar la innovación empresarial y el desarrollo productivo regional.

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Articles

# Cálculo de los Índices de Complejidad en México: Propuesta para una estimación más periódica y robusta

*Manuel Gómez-Zaldívar*, Fernando Gómez-Zaldívar**, José Luis Carrillo Ramírez****

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## Resumen:

El Índice de Complejidad Económica (ICE) y el Índice de Complejidad de los Productos (ICP), propuestos por Hidalgo y Hausmann (2009), son medidas que cuantifican la sofisticación del conocimiento productivo que las economías (las industrias) poseen (requieren para producir). Estos índices han sido frecuentemente empleados en la literatura de geografía y desarrollo económico para el diseño óptimo de estrategias industriales. En el estudio original, los autores calculan estas medidas para países y productos empleando datos del valor de sus exportaciones. A partir de entonces, diversos estudios los han estimado a nivel subnacional empleando otras variables como: empleo, patentes, tecnologías, salarios, etc. Este artículo presenta una propuesta para una estimación más periódica y robusta de los índices en México usando una variable distinta, el número de establecimientos o unidades económicas por tipo de actividad productiva del Directorio Estadístico Nacional de Unidades Económicas (DENUE). Los resultados son consistentes, tanto para municipios como para industrias y presentan un mejor ajuste respecto al de estudios previos. Consideramos que nuestra propuesta es pertinente porque permite el diseño y evaluación más periódica de las estrategias industriales y de las políticas públicas subnacionales en materia de desarrollo económico.

**Palabras clave:** Índice de Complejidad Económica; Índice de Complejidad de los Productos; DENUE.
**Clasificación JEL:** L60; R11; R12.

## Calculation of Complexity Indices for Mexico: Proposal for a more periodic and robust estimation

## Abstract:

The Economic Complexity Index (ECI) and Product Complexity Index (PCI), proposed by Hidalgo and Hausmann (2009), are measures that quantify the sophistication of productive knowledge that economies (industries) posses (require to produce). These indexes have been frequently used in the economic geography and economic development literature for the optimal design of industrial strategies. In the original study, these authors calculated these measures for countries and products using data on the value of their exports. Since then, various studies have estimated them at the subnational level using other variables such as: employment, patents, technologies, salaries, etc. This article presents a proposal for a more periodic and robust estimation of the indices in Mexico using a different variable, the number of establishments or economic units by type of activity, this variable is obtained from the National Statistical Directory of Economic Units (DENUE, its Spanish acronym). The results are consistent, both for

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municipalities and for industries, and present a better fit compared to those of previous studies. We consider that our proposal is pertinent because it allows for the design and more periodic evaluation of industrial strategies and subnational public policies in the area of economic development.

**Keywords:** Economic Complexity Index; Product Complexity Index; DENUE.
**JEL Classification:** L60; R11; R12.

## 1. Introducción

La teoría de la complejidad económica [Hidalgo y Hausmann (2009) y Hausmann *et al.* (2011)] ha sido empleada considerablemente en los últimos años en las áreas de geografía económica, desarrollo internacional y estudios de innovación. Ésta establece que las economías tienen capacidades productivas que dependen de la existencia de diversos factores. Por una parte, los insumos tradicionales: materias primas, mano de obra, capital y todo tipo de infraestructura. Por otro lado, el sistema de justicia, el estado de derecho, y todo tipo de instituciones que las economías crean. Y, de forma específica, resalta la importancia del *conocimiento tácito* o *know-how* que las economías adquieren por la práctica o mediante la experiencia, razón por la cual resulta difícil de obtener y de transferir. De la combinación de estos distintos factores productivos, i.e., a través de una red que combina los distintos conocimientos productivos existentes, mediante las organizaciones y los mercados que tiene cada economía, surge el nivel de complejidad económica o el nivel de capacidad productiva. Así, las economías producen bienes y servicios acorde con la cantidad de capacidades productivas que poseen las personas y sus formas de organización (empresas privadas, instituciones públicas, etc.), por lo que las economías que cuentan con un stock de conocimientos productivos más vasto tienen un mayor potencial para producir una mayor diversidad de productos y servicios más sofisticados, i.e., con un mayor valor agregado; además, mayor capacidad para desarrollar o crear nuevos. De esta manera el estudio de la complejidad económica busca comprender los resultados visibles de estas interacciones sistémicas ocultas, así como los diversos procesos socioeconómicos a los que estos dan forma y que dan como resultado el crecimiento, el desarrollo, el cambio tecnológico, la desigualdad de ingresos, las disparidades espaciales, la resiliencia (Balland *et al.*, 2022).

De acuerdo con Hidalgo (2021), las distintas métricas propuestas en la teoría de la complejidad económica tienen dos principales aplicaciones. Primero, el marco metodológico utiliza métodos de reducción de la dimensionalidad—de datos sobre actividades económicas en distintas regiones (como exportaciones de bienes por país o región, o empleo por estado e industria)—para construir indicadores que reflejen: i) los conocimientos o capacidades relativas que tienen las economías o Índice de Complejidad Económica (ICE); y, ii) los conocimientos o capacidades relativas necesarias para fabricar productos o prestar servicios o Índice de Complejidad de los Productos (ICP). El ICE ha recibido vasto interés académico porque diversos estudios han documentado regularidades empíricas importantes: i) significante correlación positiva del ICE con los niveles de riqueza (PIB per cápita) de las economías, véase Hidalgo y Hausmann (2009), entre otros; ii) conveniente para anticipar las tasas de crecimiento futuro de las economías, el ICE está positivamente relacionado con éstas, véase Hausmann *et al.* (2011), entre otros; iii) asociado a los niveles de desigualdad en las economías, las economías más complejas tienden a tener una distribución del ingreso más justa, véase Hartmann *et al.* (2017), entre otros; iv) relacionado con los flujos de Inversión Extranjera Directa (IED), las economías más complejas o las actividades económicas más complejas tienden a recibir mayores flujos de IED, véase Gómez-Zaldívar *et al.* (2021); v) hay una asociación entre complejidad económica y emisiones de gas que producen efecto invernadero, véase Romero y Gramkow (2021). Por su parte, el ICP permite clasificar los productos o actividades económicas con base en su nivel de sofisticación y que, por ende, podrían priorizarse en las estrategias industriales por ser las mejores apuestas para impulsar las capacidades productivas y el desarrollo económico local.

Segundo, la métrica de afinidad que calcula la conexión entre una actividad específica y una ubicación. Esta métrica explica la dependencia del camino (i.e., la dependencia de los resultados económicos actuales de los resultados anteriores, en lugar de simplemente en las condiciones actuales), y predice qué actividades crecerán o disminuirán en una ubicación, por lo que han sido utilizadas a nivel internacional en el área de geografía económica para analizar la evolución de las industrias. A partir de esta métrica, el marco metodológico de complejidad económica propone medidas adicionales (proximidad, distancia de capacidad, valor de oportunidad, ganancia de oportunidad, etc.) para identificar oportunidades específicas de diversificación productiva considerando las capacidades productivas existentes en cada región, así como estimar el impacto esperado en el nivel de su complejidad económica (Hausmann, *et al.*, 2011). El conjunto de herramientas cuantitativas propuesto ha sido especialmente útil a nivel internacional para diseñar estrategias industriales basadas en el lugar, i.e., considerando las características existentes de las estructuras productivas locales. Ejemplo de ello son la Estrategia de Especialización Inteligente de Europa (Balland et *al.*, 2019; Foray, David y Hall 2009; Montresor y Quatraro 2020); las zonas económicas especiales de China (Zheng et *al.*, 2016; De Waldemar y Poncet, 2013); la estrategia de Diversificación Inteligente de México (Gómez-Zaldívar F. et *al.*, 2019) o la Iniciativa de Superclusters de Canadá (Wang y Turkina, 2020).

La principal aportación de este trabajo es mostrar que los índices, ICE e ICP, pueden ser calculados a partir de una nueva variable (número de empresas) con resultados similares a los que se han sido obtenidos en trabajos anteriores, aplicados a la economía mexicana. Estos trabajos han empleado otras variables para calcular dichos índices: número aproximado de población ocupada (PO); valor agregado por persona ocupada (VAPO), personal ocupado total (POT) y producción bruta total por personal ocupado (PBPO). Estas variables provienen principalmente de los Censos Económicos generados por el Instituto Nacional de Estadísica y Georgrafía (INEGI) cada 5 años. Nuestros resultados revelan que los investigadores interesados en la economía mexicana ahora podrán emplear datos que son publicados más periódicamente, ya que la variable propuesta está disponible anualmente desde 2010), para hacer análisis relativo a la complejidad, de estados, municipios, y actividades económicas de México, como métricas relevantes para el diseño y evaluación de estrategias de desarrollo económico local.

El resto del documento se organiza de la siguiente manera: en la Sección de Antecedentes se mencionan los estudios que calculan la complejidad económica a nivel subnacional en diferentes países, haciendo especial énfasis en los trabajos aplicados a México; en la Sección de Datos y Metodología se precisa los datos empleados en este y los otros estudios, para generar los índices ICE e ICP que serán comparados; y se explica la metodología empleada; finalmente, en la Sección de Comentarios Finales se resaltan las principales implicaciones de la propuesta en materia de diseño de política pública y seguimiento de estrategias industriales locales.

## 2. Antecedentes

En el proceso del desarrollo económico, los países y las regiones evolucionan sus ventajas comparativas adquiriendo nuevas capacidades productivas en forma de conocimientos y tecnología que les permite producir bienes más diversos y sofisticados. Hausmann *et al.* (2011) establecen que estas capacidades o conocimientos productivos son difíciles de observar (por lo tanto, de medir), pero es posible inferir las cantidades relativas que las economías poseen a partir de la diversidad de bienes y servicios que producen. La complejidad económica se centra en la dualidad entre los insumos y productos, pero a diferencia de los enfoques tradicionales que utilizan medidas agregadas o asumen la naturaleza de los insumos (i.e., capital, trabajo, conocimiento, ect.), los métodos de complejidad económica contemplan datos exactos sobre miles de actividades económicas para considerar tanto los factores abstractos de producción como la forma en que se combinan en miles de productos (Hidalgo, 2021).

En el trabajo original, Hidalgo y Hausmann (2009) calculan el ICE e ICP para países y productos empleando datos de exportación de bienes.[1] *El hecho de que a nivel internacional la complejidad económica de los países y los productos se mida usando datos de exportaciones es explicado por la disponibilidad de datos, no por un aspecto fundamental de la teoría*. En este sentido, muchas de las limitaciones de los esfuerzos actuales para medir de mejor manera la complejidad vienen de contar con mejores datos; de existir estos, la medida reflejaría más exactamente las capacidades relativas de las economías (Hidalgo, 2020). Al respecto, Koch (2021) señala algunas limitantes del uso de la variable de exportaciones para el cálculo de

[1] Sus resultados son robustos con tres fuentes/clasificaciones de productos exportados: i) Clasificación Estándar de Comercio Internacional (SITC, por sus siglas en inglés); productos desagregados a nivel de 4 dígitos, incluyen 772 productos y 129 países; ii) base de datos COMTRADE; productos desagregados a 4 dígitos, tienen 1241 productos y 103 países; iii) Sistema de Clasificación Industrial de América del Norte (SCIAN); nivel de desagregación a 6 dígitos, con 318 productos y 150 países.

los índices de complejidad económica y proponen el valor agregado como una variable más adecuada para su cálculo. Argumenta que en tiempos de cadenas de valor globales cada vez más integradas, las exportaciones brutas pueden transmitir una imagen inexacta del desempeño económico de un país, ya que también incorporan valor agregado extranjero y exportaciones doblemente contabilizadas. En su trabajo calcula la complejidad económica con base en el valor agregado en la estructura de las exportaciones de un país, encontrando que el poder explicativo de las tasas de crecimiento del PIB per cápita para una muestra de 40 países de ingresos medianos bajos a altos es considerablemente mayor.

Ante estas observaciones sobre los datos, los estudios internacionales de complejidad económica a nivel subnacional han hecho uso de diversas variables económicas para estimar los índices ICE e ICP. Balland y Rigby (2017) miden la complejidad del conocimiento en las ciudades de EE. UU. y exploran cómo la difusión espacial del conocimiento está vinculada a la complejidad utilizando más de dos millones de registros de patentes de la Oficina de Marcas y Patentes de EE. UU. que identifican la estructura tecnológica de las áreas metropolitanas de este país en términos de las clases de patentes en las que son más activas entre 1975 y 2010. Gao y Zhou (2018) estiman el índice de complejidad económica regional (ICE) utilizando el número de empresas que cotizan en bolsa en dos importantes mercados bursátiles (Shanghai y Shenzhen) de China entre 1990 y 2015, de un total de 2690 empresas ubicadas a lo largo de 31 provincias (o municipios) en China, pertenecientes a 70 categorías de la clasificación de la industria emitida por la Comisión Reguladora de Valores de China. En su estudio vinculan el ICE con el desarrollo económico y la desigualdad de ingresos, encontrando que el poder explicativo de la ICE es positivo para el primero y negativo para el segundo. Mewes y Broekel (2022) evalúan la complejidad de las actividades tecnológicas en 159 regiones europeas utilizando datos de patentes de la base de datos REGPAT de la OCDE. En su estudio relacionan la complejidad de las regiones con su crecimiento económico entre 2000 y 2014, encontrando que la complejidad tecnológica es un indicador importante del crecimiento económico regional. Wohl (2020) aplica el método de reflexiones utilizando datos de 422 ciudades de EE. UU. y 738 ocupaciones. En su estudio encuentran que el método de reflexiones[2] proporciona resultados que están más fuertemente correlacionados con los salarios en las ciudades de EE. UU., i.e., las ciudades que se vuelven más diversas tienden a tener mayores aumentos en los salarios, mientras que las ocupaciones que se vuelven más ubicuas[3] tienden a tener menores aumentos (o incluso disminuciones) en los salarios. Fritz y Manduca (2021) calculan las medidas de complejidad económica para las áreas metropolitanas de EE. UU. para el período 1998-2015 utilizando datos de empleo, encontrando que la complejidad metropolitana se asocia con mayores ingresos, aunque en menor medida recientemente que en el pasado. Otros estudios a nivel subnacional son: Zhu *et al.* (2020) miden la complejidad de regiones en China; Pérez-Balsalobre, Llano-Verduras y Díaz-Lanchas (2019) hacen lo mismo para las de España; Antonietti y Burlina (2022) calculan la complejidad de regiones en Italia; Herrera, Strauch y Bruno (2020) estudian la complejidad de los diversos estados Brasileños; Díaz-Lanchas *et al.* (2018) lo hacen para diversas áreas urbanas brasileñas Chakraborty *et al.* (2020) miden la complejidad de las prefecturas en Japón; y Chávez *et al.* (2017) estudian la complejidad de los estados de México, entre otros.

En el caso de México, los datos disponibles de exportaciones son una limitante para analizar las capacidades productivas a nivel subnacional (estados y municipios),[4] razón por la cual los estudios de complejidad económica han utilizado otras variables para estimar los índices ICE e ICP, variables obtenidas de los Censos Económicos. Adicionalmente, el uso de datos de exportaciones para el cálculo del ICE y IPC puede no ser conveniente para calcular las capacidades productivas de las economías regionales; especialmente (como es el caso de los estados en México), si las economías bajo análisis, por alguna razón, tienen bajos niveles de intercambio comercial.[5]

[2] El método de reflexiones se refiere al proceso iterativo para el cálculo de los índices de complejidad. Para mayor detalle, véase sección de Metodología.

[3] La ubicuidad se una industria u ocupación se refiere al número de regiones que se especializan en estas. Una mayor (menor) ubicuidad de la industria u ocupación refleja una menor (mayor) sofisticación de estas.

[4] A nivel subnacional, los datos de exportaciones entre estados solo existen a nivel subsector económico (código desagregado a 3 dígitos del Sistema de Clasificación Industrial de América del Norte (SCIAN) a partir de 2007. Además, solo contemplan 26 subsectores de los 94 que contempla el SCIAN, lo que limita la confianza en la metodología empleada para el cálculo confiable de los índices.

[5] En este caso, se subestimarían sus capacidades productivas.

En el primer estudio subnacional para México, Chávez *et al.* (2017) estudian la complejidad de los estados de México, ésta es calculada empleando la variable de personas empleadas a nivel de Clase de Actividad Económica (CAE)—nivel de desagregación de 6-dígitos del SCIAN—utilizando la fuente de información económica-industrial más completa y confiable del país, los Censos Económicos del INEGI. Sus resultados sugieren que los estados del país difieren marcadamente en cuanto a las actividades en las que se especializan, encontrando, entre otras cosas, un patrón regional claro que muestra que los estados del norte son más complejos, los de la región central tienen un nivel intermedio de complejidad y los del sur tienen los niveles más bajos de complejidad, lo que contribuye en cierta medida a explicar sus diferentes patrones de crecimiento. A partir de este artículo, diversos estudios han estimado la complejidad económica a nivel subnacional en México utilizando otras variables como personal ocupado total[6], producción bruta por personal ocupado[7] y valor agregado por persona ocupada.[8]

Gómez Zaldívar *et al.* (2019) utilizan la variable de personal ocupado total de los Censos Económicos para caracterizar el nivel de complejidad de los estados más rezagados donde el gobierno de México proponía impulsar Zonas Económicas Especiales, con el fin de identificar oportunidades de desarrollar nuevas industrias de mayor complejidad. Hausmann, *et al.* (2021) calculan la complejidad económica con la variable empleo para explicar las brechas salariales del país; encuentran que la complejidad económica explica una fracción mayor de la brecha salarial que cualquier factor individual para el caso del estado de Chiapas. Gómez-Zaldívar, *et al.* (2021) calculan de forma similar los índices de complejidad económica, encontrando que ésta está asociada a la distribución de la Inversión Extranjera Directa (IED) entre los estados mexicanos y muestran cómo los estados rodeados de estados con un alto nivel de complejidad económica tienden a recibir más IED. De forma más reciente, Gómez-Zaldívar y Gómez-Zaldívar (2023) calculan los índices de complejidad a nivel municipal y actividad económica en México con diferentes variables: personal ocupado, producción bruta por trabajador y valor agregado por persona ocupada. Encuentran tres resultados principales: i) que los índices de complejidad calculados con estas variables son robustos, no dependen de qué variable se utiliza en el cálculo; ii) que las diferencias en los principales indicadores económicos municipales (como niveles de riqueza, tasas de crecimiento económico y salarios) están asociadas con diferencias en las capacidades productivas; y, iii) que la mayoría de las nuevas empresas en municipios complejos (no complejos) generalmente tienden a participar en actividades económicas más sofisticadas/de mayor valor agregado (menos sofisticadas/de menor valor agregado).

La mayoría de estos estudios han hecho uso de los datos de los Censos Económicos para analizar la complejidad económica usando datos al nivel máximo de desagregación industrial [Clase de Actividad Económica (CAE), desagregación a 6-dígitos del SCIAN] y geográfica, en el que se consideran más de 880 actividades económicas, localizadas en más de 2,400 municipios de México. No obstante, la disponibilidad de la información de las actividades económicas y servicios gubernamentales en los Censos Económicos y el principio de confidencialidad de INEGI, bajo el cual no pueden publicarse los datos de indicadores directos de regiones donde existen menos de 3 unidades económicas por actividad productiva, son las principales limitaciones para realizar el análisis de complejidad económica a nivel subnacional en México, lo que afecta principalmente a localidades pequeñas y rezagadas. Adicionalmente, la temporalidad con la que se producen los datos (por el alcance del levantamiento, esta información se produce por el INEGI cada 5 años), limita el análisis de la complejidad económica en el corto o mediano plazo, lo que disminuye la capacidad de los gobiernos subnacionales de diseñar y evaluar estrategias industriales y políticas públicas basadas en datos.

[6] Personal ocupado total: Comprende a todas las personas que trabajaron durante el periodo de referencia dependiendo contractualmente o no de la unidad económica, sujetas a su dirección y control.

[7] Producción bruta total por personal ocupado total: Valor de todos los bienes y servicios producidos o comercializados por la unidad económica como resultado del ejercicio de sus actividades, comprendiendo el valor de los productos elaborados; el margen bruto de comercialización; las obras ejecutadas; los ingresos por la prestación de servicios, así como el alquiler de maquinaria y equipo, y otros bienes muebles e inmuebles; el valor de los activos fijos producidos para uso propio, entre otros, entre el personal ocupado total.

[8] Valor agregado por persona ocupada: Valor adicional que en promedio generó cada persona ocupada a la producción, durante cada etapa del proceso de trabajo. Resulta de dividir el valor agregado entre el personal ocupado total.

Una de las propuestas más recientes para la estimación periódica de los índices ICE e ICP a nivel subnacional en México se publica en el portal de DataMéxico,[9] el cual presenta los cálculos empleando los datos del DENUE, bajo ciertas aproximaciones del número de empleados por actividad económica. De forma específica, tal como se describe en el portal, utilizan un proxy del número de trabajadores por actividad económica, debido a que el Directorio no entrega los valores exactos del número de trabajadores, sino que proporcionan un rango indicando el límite superior e inferior del mismo. El proxy se obtiene como el punto medio de los límites del rango informado. En el caso del último rango, donde no se tiene un límite superior, se utiliza el mínimo informado (251 empleos para grandes empresas), lo que puede limitar la precisión de la estimación.

Este trabajo propone medir el ICE e ICP con datos alternativos a los que hasta ahora se han empleado en México, para realizar análisis más periódicos y con una mayor certeza de que estos reflejan adecuadamente las estructuras productivas al nivel geográfico e industrial más desagregado, ya que se obtienen resultados similares a los índices calculados con otras variables en trabajos anteriores.[10] Específicamente, se propone utilizar la variable de número de unidades económicas o número de establecimientos,[11] que se obtiene del DENUE, para la estimación de los índices de complejidad. El DENUE se elabora dos veces al año desde 2010, contiene información de las unidades económicas/empresas activas del país como localización, tamaño del establecimiento por rangos, clase de actividad económica a la que se dedica, etc. Respecto al nivel de desagregación industrial, los datos de establecimientos del DENUE se presentan, al igual que los Censos Económicos, al nivel de más desagregado (6-dígitos del SCIAN). No obstante, una ventaja adicional es que el dato de número de unidades económicas, al no ser confidencial según las políticas del INEGI, permiten tener más de 100 clasificaciones de actividades económicas adicionales, incluyendo actividades de gobierno, organizaciones civiles, servicios públicos, etc., lo que permite tener una mejor medida de las capacidades productivas existentes en una región.

La propuesta de uso de la variable número de establecimientos o unidades económicas está sustentada en la teoría de complejidad económica, la cual sostiene que el conocimiento solo puede acumularse, transferirse y preservarse si está integrado en redes de individuos y organizaciones que lo utilicen, i.e., los mercados y las organizaciones como unidades de almacenamiento y vehículos que permiten darle al conocimiento un uso productivo (véase Hausmann *et al.,* 2011 e Hidalgo *et al*., 2015). De esta manera, conocer el número de unidades económicas o establecimientos y la principal actividad productiva que llevan a cabo nos permite caracterizar de mejor manera la estructura económica de cada región, logrando llegar a niveles geográficos municipal y/o estatal, y al nivel industrial más desagregado en México (CAE), considerando la mayor diversidad de las capacidades productivas que los datos existentes permiten.

## 3. Datos y metodología

### Datos

Para calcular el ICE y el ICP en este trabajo, se emplea la variable número de establecimientos o unidades económicas por región y actividad económica, que se obtiene del DENUE.[12]

Los resultados obtenidos son comparados con los calculados en trabajos anteriores, generados con otras variables distintas.[13] Cabe destacar, que para que la comparación sea lo más justa posible, el cálculo

[9] Los valores de los índices calculados por la Secretaría de Economía se encuentran en: https://datamexico.org/es/profile/economic_complexity/1

[10] A nivel internacional, específicamente para China, Gao y Zhou (2018) han empleado datos sobre empresas para calcular complejidad económica. Pero para el caso de México este trabajo es el primero, hasta donde nosotros sabemos.

[11] Unidad económica que, en una sola ubicación física, asentada en un lugar de manera permanente y delimitada por construcciones e instalaciones fijas, combina acciones y recursos bajo el control de una sola entidad propietaria o controladora para realizar alguna actividad económica sea con fines de lucro o no. Incluye a las viviendas en las que se realizan actividades económicas.

[12] El código usado para obtener esta variable de la página del DENUE está disponible para quien lo solicite.

[13] Son comparados en dos distintos años, 2014 y 2019. Años para los que existen cálculos del ICE e ICP con las variables de los Censos Económicos.

de todos los índices empleó exactamente la misma metodología, Hidalgo y Hausmann (2009), que se describirá en la segunda parte de esta sección; por lo que, la única diferencia entre ellos es la variable empleada para calcularlos.

Los estudios anteriores que han calculado dichos índices emplean distintas variables, que se describen a continuación:

*a) Fuente: DENUE; variable: número de trabajadores*

De acuerdo a la página web de DataMéxico, la Secretaría de Economía emplea una variable de empleo del DENUE para calcular el ICE e ICP. Específicamente, utilizan el número aproximado de población ocupada, por región y grupo industrial. Ellos calculan los ICE a diferentes niveles geográficos: estado, zona metropolitana y municipio; y los ICP a diferentes niveles de clasificación: subsectores, ramas, subramas y CAE.

*b) Fuente: Censos económicos; variable: valor agregado por persona ocupada*

Estudios previos que analizan a la economía mexicana a nivel municipal han empleado datos de los Censos Económicos con el mayor nivel desagregación (CAE, 6-dígitos del SCIAN), utilizando la variable valor agregado por persona ocupada (véase Gómez-Zaldívar y Gómez-Zaldívar, 2023).[14] Por su definición, es importante destacar el uso de esta variable, porque la literatura de complejidad económica señala que los cálculos usando variables que permitan caracterizar de mejor manera el valor del conocimiento productivo que cada región, son la mejor opción para caracterizar las capacidades productivas existentes en ella y/o que son requeridas para la producción de cada bien.

*c) Fuente: Censos económicos; variable: personal ocupado total y producción bruta total por personal ocupado.*

Adicionalmente, también se incluye en la comparación los cálculos del ICE e ICP que se obtienen cuando se emplean otras dos variables del Censo Económico: personal ocupado total y producción bruta total por personal ocupado. Lo cálculos usando estas otras dos variables no han aparecido en trabajos previos.

Aun con las bondades de la desagregación industrial y geográfica, las variables de las bases de datos empleadas en trabajos anteriores tienen algunos inconvenientes o desventajas. Como se mencionó, el mayor limitante de los Censos Económicos es la temporalidad con la que se recaba y publica esta información, lo que ocurre cada 5 años. Esta temporalidad, de facto, limita la capacidad de evaluar y dar seguimiento en el más corto plazo a los cambios económicos causados por políticas públicas, inversiones o decisiones empresariales que se lleven a cabo en los estados y municipios.[15] Por su parte, la variable número de trabajadores por unidad económica del DENUE utilizada en el portal de Data México, por la Secretaría de Economía, es solo una aproximación. Ya que este dato es reportado por rangos, los cálculos se hacen con el punto medio del rango del número de trabajadores reportados por cada unidad económica. Esto podría ocasionar distorsiones en la medición base de las estructuras productivas y la especialización de las regiones.

## Metodología

La metodología empleada en este trabajo para calcular los ICE y los ICP es exactamente la propuesta por Hidalgo y Hausmann (2009), misma que ha sido empleada en distintos trabajos anteriores aplicados

[14] La variable de valor agregado de los Censos Económicos mide el valor de la producción que se añade durante el proceso de trabajo por la actividad creadora y de transformación del personal ocupado, el capital y la organización (factores de la producción), ejercida sobre los materiales que se consumen en la realización de la actividad económica.

[15] Analizar el impacto de una política pública o industrial a nivel regional debería ser un campo de especial interés para la población y los gobiernos locales.

a la economía mexicana, tanto a nivel estatal como municipal. [16] Ésta se describe a continuación.

Primero, la variable empleada para medir complejidad económica—en nuestro caso Unidades Económicas por municipio y por actividad económica—se ordena en una matriz de *i*j*, $M_{i,j}$, donde *i* denota las regiones (municipios) y *j* denota las actividades económicas (clases de actividad económica). En nuestro caso, que usamos la variable número de unidades económicas, el número que contiene la celda (*i*, *j*) representa el número de unidades económicas o empresas que tiene la región *i* que realizan la actividad económica *j*.

Segundo, la matriz $M_{i,j}$ es transformada a una matriz binaria (de ceros y unos), $M_{i,j}^{B}$; donde 1 indica que la región *i* está especializada en la actividad económica *j*, y cero que no; otra manera de interpretarlo es, la celda con 1 indica que la actividad económica *j* está localizada en la región *i*, y cero indica que no. Para esta transformación se emplea la definición de coeficiente de localización (CL), medida empleada regularmente en la literatura de economía regional.

$$CL_{i,j} = \frac{\dfrac{UE_{i,j}}{\sum_{j=1}^{n_j} UE_{i,j}}}{\dfrac{\sum_{i=1}^{n_i} UE_{i,j}}{\sum_{j=1}^{n_j}\sum_{i=1}^{n_i} UE_{i,j}}}$$

donde $UE_{i,j}$ es el número de unidades económicas o empresas en la región *i* que se dedican a la actividad económica *j*; $\sum_{j=1}^{n_j} UE_{i,j}$ es el total de unidades económicas en la región *i*, independientemente de la actividad económica *j* que realicen; $\sum_{i=1}^{n_i} UE_{i,j}$ es el total de unidades económicas en todas las regiones *i* dedicadas a la actividad económica *j*; finalmente, $\sum_{j=1}^{n_j}\sum_{i=1}^{n_i} UE_{i,j}$ es total de unidades económica en todas las regiones *i* independientemente de su actividad económica *j*.

La celda $m_{i,j}^{B}$ de la matriz $M_{i,j}^{B}$ se define como $m_{i,j}^{B} = \begin{cases} 1 & si \quad CL_{i,j} \geq 1 \\ 0 & de\ otra\ manera \end{cases}$

Esto significa que la región *i* es considerada como especializada en la actividad económica *j* si la proporción de empresas que hay en esa región dedicadas a la actividad económica *j* es igual o mayor a la proporción análoga a nivel nacional.

Tercero, usando la matriz de ceros y unos, $M_{i,j}^{B}$, se definen los vectores de diversidad y ubicuidad. El vector diversidad es de dimensión $1^{*}i$, cada una de sus entradas indica el número de actividades económicas en las que están especializadas las regiones consideradas. Se obtiene sumando cada uno de los renglones de la matriz $M_{i,j}^{B}$.

Diversidad de los estados $\kappa_{D,0} = \sum_{j=1}^{j_n} m_{i,j}$

El vector ubicuidad es de dimensión $j^{*}1$, cada una de sus entradas indica el número de regiones que están especializadas en cada una de las actividades económicas. Se obtiene sumando cada una de las columnas de la matriz $M_{i,j}^{B}$.

Ubiquidad de las actividades económicas $\kappa_{U,0} = \sum_{i=1}^{i_n} m_{i,j}$

Finalmente, estos dos vectores se combinan usando el método de reflexiones para obtener el ICE y el ICP. El método de reflexiones es un proceso iterativo que combina los vectores de diversidad y ubiquidad, se definide de la siguiente manera,

[16] Estudios que calculan el ICE o ICP a nivel estatal, son: Chávez et al. (2017); Gómez-Zaldívar et al. (2020); Gómez-Zaldívar et al. (2021); Gómez-Zaldívar y Llanos-Guerrero (2021); y Gómez-Zaldívar et al. (2022). A nivel municipal, véase Gómez-Zaldívar y Gómez-Zaldívar (2023).

$$\kappa_{D,N} = \frac{1}{\kappa_{s,0}} \sum_{j=1}^{j_n} m_{i,j} \cdot \kappa_{U,N-1}$$

$$\kappa_{U,N} = \frac{1}{\kappa_{a,0}} \sum_{i=1}^{i_n} m_{s,a} \cdot \kappa_{D,N-1}$$

Esto implica que, en cada nueva iteración, un nuevo vector de diversidad y ubiquidad es obtenido. Cuando el proceso finalmente alcanza un punto fijo, los últimos vectores del proceso son el ICE e ICP. Las iteraciones continúan hasta que las clasificaciones permanecen sin cambio por tres iteraciones consecutivas.

## 4. Resultados

La Tabla 1 muestra las correlaciones entre los ICE calculado por nosotros, con la variable número de el número de establecimientos o unidades económicas, y los resultados calculados con otras 4 distintas fuentes (variables):[17] uno del DENUE [número aproximado de población ocupada (PO); tres de los Censos Económicos [valor agregado por persona ocupada (VAPO), personal ocupado total (POT) y producción bruta total por personal ocupado (PBPO)].

Los resultados ilustran lo siguiente: i) son robustos, en ningún caso la correlación entre los distintos ICE es menor a 0.89, lo que implica que todos los datos que reflejan la misma estructura económica regiones-productos; ii) de los dos, nuestro cálculo del ICE a partir del número de establecimientos del DENUE, es el que tiene la correlación mayor con todos los ICE generados con las variables de los Censos Económicos. Considerando que los Censos Económicos presentan la información más confiable y desagregada con la que se puede caracterizar las estructuras económicas regionales de México y estimar las métricas de complejidad económica, esto implica que los cálculos de los índices de complejidad a partir del número de unidades económicas del DENUE presentan una mejor aproximación en términos generales, y que permitirían un mejor evaluación de las estructuras económicas locales en el corto plazo, en lo particular; iii) las correlaciones entre los ICE generados con variables de los Censos Económicos son altas, la más alta es 0.9975, entre los ICE generados con valor agregado por persona ocupada y producción bruta por personal ocupado. En ningún caso la correlación es inferior a 0.9425. De la misma forma, la correlación de los ICE obtenidos a partir de las dos variables del DENUE también es alta, 0.9725. Todo esto implica que las variables empleadas son robustas.

La Tabla 2 muestra las correlaciones entre los ICP calculados, con las 5 distintas variables, con datos del 2019. Los resultados en la Tabla 2 implican las mismas conclusiones antes mencionadas, el ICP calculado a partir del número de el número de establecimientos o unidades económicas del DENUE presenta una más alta correlación con los ICP generados con las variables de los Censos Económicos que el ICP obtenido por la Secretaría de Economía con el número de trabajadores. La diferencia importante es que las correlaciones de la Tabla 2, entre todos los ICP, son significativamente menores que las de la Tabla 1, entre los ICE.

[17] ICE y ICP calculados en este trabajo no se presentan en este documento, ya que son muy extensos, pero están disponibles en un archivo de Excel, que también incluye los resultados obtenidos por otros estudios publicados y resultados que no se han publicado anteriormente que se calculan con otras variables de los Censos Económicos.

Tabla 1.
Correlaciones ICE (2019)

| Autor, fuente de los datos (variable empleada) | Nuestro trabajo DENUE, (NE) | Secretaría de Economía, DENUE, (PO) | Gómez-Zaldívar et al. (2023), Censos Económicos, (VAPO) | No publicado, Censos Económicos, (POT) | No publicado, Censos Económicos, (PBPO) |
|---|---|---|---|---|---|
| Nuestro trabajo, DENUE, (NE) | 1 | 0.9725 | 0.9508 | 0.9118 | 0.9467 |
| Secretaría de Economía, DENUE, (PO) | --- | 1 | 0.9154 | 0.8915 | 0.9117 |
| Gómez-Zaldívar et al. (2023) Censos Económicos, (VAPO) | --- | --- | 1 | 0.9425 | 0.9975 |
| No publicado, Censos Económicos, (POT) | --- | --- | --- | 1 | 0.9451 |
| No publicado, Censos Económicos, (PBPO) | --- | --- | --- | --- | 1 |

El Apéndice 1 muestra algunas gráficas de los valores ICE 2019 usadas para el cálculo estas correlaciones.

Tabla 2.
Correlaciones ICP (2019)

| Autor, fuente de los datos (variable empleada) | Nuestro trabajo DENUE, (NE) | Secretaría de Economía, DENUE, (PO) | Gómez-Zaldívar et al. (2023), Censos Económicos, (VAPO) | No publicado, Censos Económicos, (POT) | No publicado, Censos Económicos, (PBPO) |
|---|---|---|---|---|---|
| Nuestro trabajo, DENUE, (NE) | 1 | 0.9548 | 0.8764 | 0.8628 | 0.8722 |
| Secretaría de Economía, DENUE, (PO) | --- | 1 | 0.7803 | 0.8061 | 0.7762 |
| Gómez-Zaldívar et al. (2023,) Censos Económicos, (VAPO) | --- | --- | 1 | 0.9459 | 0.9980 |
| No publicado, Censos Económicos, (POT) | --- | --- | --- | 1 | 0.9434 |
| No publicado, Censos Económicos, (PBPO) | --- | --- | --- | --- | 1 |

La Tabla 3 muestra las correlaciones entre los ICE calculados, con las 5 distintas variables, con datos del 2014. Nuevamente, los resultados implican las mismas conclusiones antes mencionadas.

**Tabla 3.**
**Correlaciones ICE (2014)**

| **Autor, fuente de los datos (variable empleada)** | **Nuestro trabajo DENUE, (NE)** | **Secretaría de Economía, DENUE, (PO)** | **Gómez-Zaldívar et al. (2023), Censos Económicos, (VAPO)** | **No publicado, Censos Económicos, (POT)** | **No publicado, Censos Económicos, (PBPO)** |
|---|---|---|---|---|---|
| Nuestro trabajo, DENUE, (NE) | 1 | 0.8754 | 0.9283 | 0.9121 | 0.9137 |
| Secretaría de Economía, DENUE, (PO) | --- | 1 | 0.8625 | 0.8511 | 0.8680 |
| Gómez-Zaldívar et al. (2023,) Censos Económicos, (VAPO) | --- | --- | 1 | 0.9422 | 0.9955 |
| No publicado, Censos Económicos, (POT) | --- | --- | --- | 1 | 0.9395 |
| No publicado, Censos Económicos, (PBPO) | --- | --- | --- | --- | 1 |

Finalmente, la Tabla 4 muestra las correlaciones entre los ICP calculados con datos del 2014. En esta fecha, no contamos con los datos del ICP calculados por la Secretaría de Economía, ya que no están disponibles en su página de internet, por lo tanto, la tabla es de menor dimensión.

**Tabla 4.**
**Correlaciones ICP (2014)**

| **Autor, fuente de los datos (variable empleada)** | **Nuestro trabajo DENUE, (NE)** | **Gómez-Zaldívar et al. (2023), Censos Económicos, (VAPO)** | **No publicado, Censos Económicos, (POT)** | **No publicado, Censos Económicos, (PBPO)** |
|---|---|---|---|---|
| Nuestro trabajo, DENUE, (NE) | 1 | 0.8666 | 0.8035 | 0.8233 |
| Gómez-Zaldívar et al. (2023,) Censos Económicos, (VAPO) | --- | 1 | 0.9085 | 0.8754 |
| No publicado, Censos Económicos, (POT) | --- | --- | 1 | 0.8864 |
| No publicado, Censos Económicos, (PBPO) | --- | --- | --- | 1 |

El Apéndice 2 muestra la lista de los municipios más económicamente complejos de acuerdo con las distintas medidas generadas.

## 5. Comentarios finales

Las políticas públicas de tipo industrial, dirigidas a transformar las estructuras económicas a partir de la acumulación de capacidades productivas más sofisticadas (elevar la complejidad económica), con el objetivo de promover el desarrollo económico a nivel regional, tienen grandes retos técnicos en las etapas de diseño y evaluación. Entre estos, dotar a los gobiernos subnacionales de información confiable y pertinente para identificar de forma precisa las ventajas comparativas locales a partir de las cuales se puedan diseñar estrategias industriales adaptadas a cada lugar, así como evaluar los resultados de las políticas y la evolución de las estructuras productivas en el corto y mediano plazo.

Este artículo presenta una propuesta para generar datos más periódicos que permiten diseñar y evaluar políticas regionales o locales mediante la estimación de los índices de complejidad económica para las regiones y actividades económicas en México. La propuesta de estimación utilizando la variable de establecimientos o unidades económicas no solo permite caracterizar de mejor manera las estructuras productivas regionales (pues el uso de variables como exportaciones limita el análisis de regiones con alto rezago industrial y sin intercambio comercial), sino que permiten la evaluación de las estrategias industriales y las políticas públicas en el corto y mediano plazo,[18] desde el diseño de los planes de desarrollo económico que todos los gobiernos subnacionales deben hacer al iniciar su gestión, la promoción para la atracción de inversiones específicas, hasta la formación de capital humano especializado para la industria actual y futura, con una temporalidad más adecuada para los tiempos de los gobiernos subnacionales. Más aún, dada las restricciones de capacidades institucionales y financieras de los gobiernos subnacionales, este tipo de métricas, con altos niveles de desagregación geográfica e industrial, permiten priorizar actividades económicas específicas a nivel local y el diseño de políticas públicas verticales con mayor precisión.

Incluso los gobiernos subnacionales de regiones rezagadas pueden identificar oportunidades de desarrollo industrial y elaborar planes de especialización inteligente con un alto fundamento técnico, como base para el establecimiento de estrategias colaborativas con otros niveles de gobierno, cámaras industriales, centros educativos y sociedad en general.

Como posible limitación futura, se podría identificar que el INEGI continúe con la actualización de la fuente de información con la misma periodicidad como hasta el momento lo hace y al mismo nivel de desagregación geográfica e industrial.

Considerando que la propuesta está acorde a los fundamentos de la teoría de complejidad económica, que la fuente de información permitiría un seguimiento más oportuno de las estrategias y estructuras productivas locales, así como un cálculo robusto de los indicadores de complejidad económica, la presente propuesta es de interés para cualquier análisis y toma de decisiones en materia de desarrollo económico regional y local en México.

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[18] Los resultados obtenidos con la variable que proponemos son robustos cuando se comparan con los obtenidos en trabajos previos, ya que los indicadores tienen un muy alto nivel de correlación; y, por lo tanto, pueden ser empleados con la misma confianza. Con la ventaja que se pueden generar más periódicamente.

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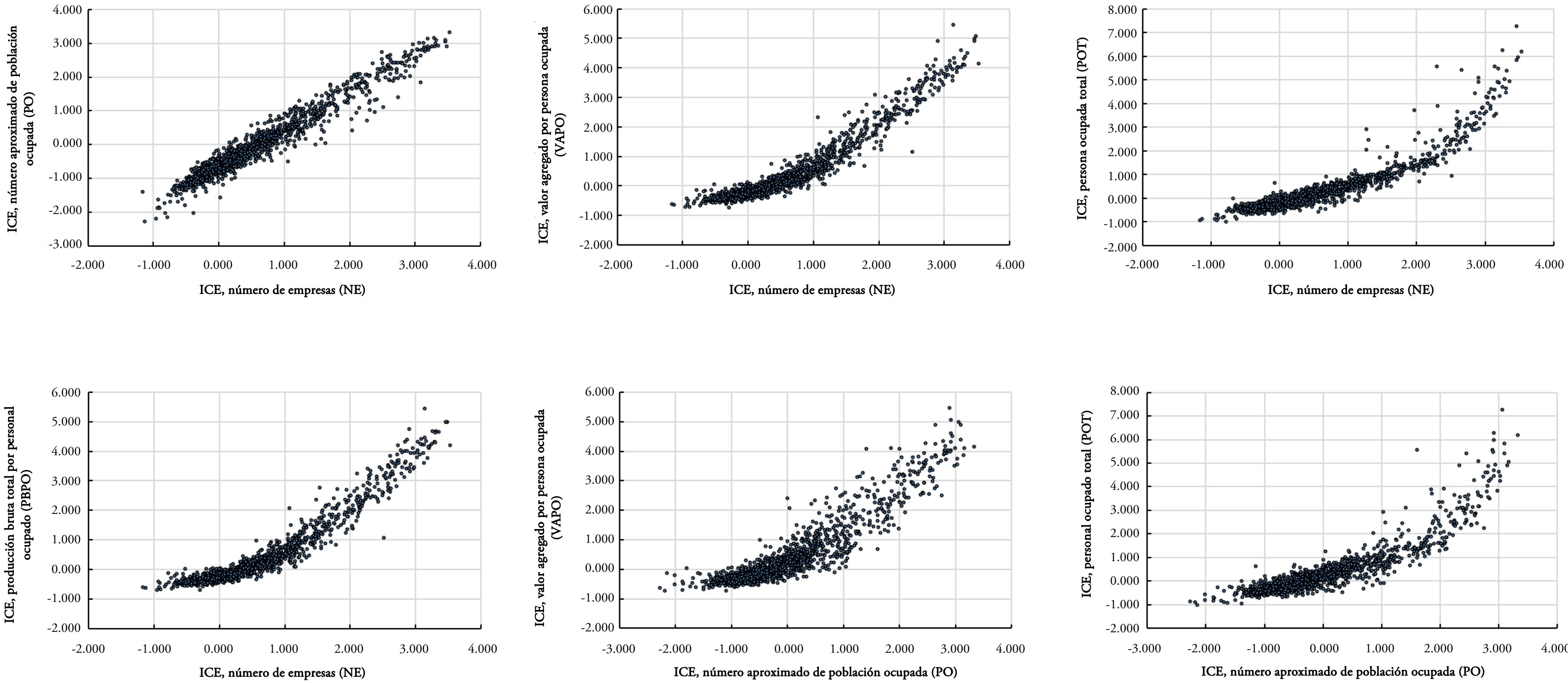
# Apéndice 1

Las Figuras en este apéndice manifiestan gráficamente lo mismo que los resultados en las Tablas 1, 2, 3 y 4. Los ICE e ICP, generados con la nueva variable que proponemos, y los ICE e ICP de trabajos previos, calculados a partir de otras variables, tiene una alta correlación.

**Gráfica A1.1**
**Comparación de los valores ICE 2019**





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## Apéndice 2

La Tabla A2.1 lista los veinte municipios más complejos tomando en cuenta las cinco diferentes variables con que se calcula el ICE, para los dos distintos años.

**Tabla A2.1**
**Municipios más complejos**

| | Municipio | | Municipio |
|---|---|---|---|
| | 2014 | | 2019 |
| 1 | Benito Juárez, CDMX. | 1 | Cuauhtémoc, CDMX. |
| 2 | Cuauhtémoc, CDMX. | 2 | Miguel Hidalgo, CDMX. |
| 3 | Azcapotzalco, CDMX. | 3 | Monterrey, N.L. |
| 4 | Miguel Hidalgo, CDMX. | 4 | Zapopan, Jal. |
| 5 | Monterrey, N.L. | 5 | Guadalajara, Jal. |
| 6 | Guadalajara, Jal. | 6 | Querétaro, Qro. |
| 7 | San Luis Potosí, S.L.P. | 7 | Hermosillo, Son. |
| 8 | Guadalupe, N.L. | 8 | San Luis Potosí, S.L.P. |
| 9 | San Pedro Garza García, N.L. | 9 | Celaya, Gto. |
| 10 | Tlalpan, CDMX. | 10 | Puebla, Pue. |
| 11 | Querétaro, Qro. | 11 | Mérida, Yuc. |
| 12 | Zapopan, Jal. | 12 | Benito Juárez, CDMX. |
| 13 | Puebla, Pue. | 13 | Tijuana, B.C. |
| 14 | León, Gto. | 14 | León, Gto. |
| 16 | Álvaro Obregón, CDMX. | 16 | Toluca, Méx. |
| 17 | Tijuana, B.C. | 17 | Álvaro Obregón, CDMX. |
| 18 | Aguascalientes, Ags. | 18 | Chihuahua, Chih. |
| 19 | Hermosillo, Son. | 19 | Apodaca, N.L. |
| 20 | Toluca, Méx. | 20 | Ciudad Juárez, Chih. |

Los resultados en la tabla ilustran lo descrito en trabajos anteriores, referente a la reorganización económica que el país está experimentado desde 1994, como consecuencia del Tratado del Libre Comercio de América del Norte (TLCAN), *la descentralización de la actividad económica.* El TLCAN ha provocado que actividades económicas, sobre todo manufacturas, emigren desde el centro del país y se establezcan, principalmente, en la región norte del país. En 2014 había siete municipios pertenecientes a Ciudad de México y Estado de México (centro del país) dentro de los 20 más complejos, para 2019 solo hay cinco. En 2014 había cuatro municipios de estados fronterizos con Estados Unidos dentro de los 20 más complejos del país, en 2019 hay seis.

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- Crear un foro de intercambio de experiencias favoreciendo la investigación y difusión de métodos, técnicas e instrumentos que afecten a la Ciencia Regional.
- Promover relaciones e intercambios a nivel internacional sobre Ciencia Regional.
- Impulsar el estudio de la Ciencia Regional en los centros docentes y de investigación.
- Promover publicaciones, conferencias y cualquier otra actividad que reviertan en una mejora del análisis y las acciones regionales.
- Colaborar con la Administración Pública, a todos los niveles, para una mejor consecución de los fines de la asociación y el desarrollo del Estado de las Autonomías.
- La asistencia técnica a la Administración Pública u otras instituciones, públicas o privadas, así como a la cooperación internacional en el ámbito de sus objetivos.

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