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Use of Analytic Methods in the Public Procurement Activity in Spain

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USE OF ANALYTIC METHODS IN THE PUBLIC PROCUREMENT ACTIVITY IN SPAIN

By

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July 2024

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

Guilherme de Sousa Moreira

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ABSTRACT

How effectively are regions allocating their resources in public procurement activities? Municipalities, regions, and nations allocate substantial financial resources to public expenditure, necessitating a highly efficient utilization of these public funds. One method to evaluate this efficiency is the Urban Scaling Laws which allows to evaluate not only the efficiency but to compare these results on different population agglomeration sizes. In this study, it will be using the methods collected from the Urban Scaling Laws methodology among the 59 regions/provinces of Spain. With the data collected, it is found that public procurement has a sub-linear behavior with the increase in the population size which translates into a more efficient spending *per capita* by the regions with a higher number of population. Decomposing these results for the three main types of contracts – Services, Goods and Works – it is possible to notice that Services and Goods contracts tend to have year after year a more linear behavior. When using the Scale Adjusted Indicators which calculates the deviations from what is their expected linear value, it was possible to compare not just provinces individually but also to compare as groups of provinces with similar regional characteristics. These results can be the base to help policymakers to make their decisions on how they can improve their efficiency in public procurement activity, as this study provides valuable insights and interesting results, both on regional and national level.

KEYWORDS

Urban Scaling Laws; Public Procurement; Comparative Analysis; Regional Development

Sustainable Development Goals (SGD):

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LIST OF ABBREVIATIONS AND ACRONYMS

NUTS Nomenclature of Territorial Units for Statistics

SAI Scaled Adjusted Indicators

USL Urban Scaling Laws

1. INTRODUCTION

Urban Scaling Laws, or USL, relate socio-economic, behavioral and physical variables to the population size of cities/regions, offering insights into their planning, resilience and economies (Carbone *et al.*, 2021; Molinero & Thurner, 2021). These laws most often reveal that larger cities tend to capture and concentrate innovations more effectively, leading to increased complexity and sophistication in urban activities and society (Bettencourt & West, 2010). The accuracy and applicability of scaling laws in urban geography are crucial for understanding urban structures, innovation cycles, metropolization, and intra-urban dynamics. Nonetheless, variations in scaling estimations due to the different definitions and attributes of city/region highlight the complexity of applying this methodology universally, emphasizing the need for sensitivity analysis to grasp the inner composition of cities concerning their size and system.

According to the Organization for Economic Operation and Development (OECD), public procurement refers to the purchase by governments and state-owned enterprises of goods, services and works (OCDE, 2013). It has become more important as tool for the public sector to fulfill policymakers (Grandia & Meehan, 2017) but also as tool to achieve sustainable goals (Brammer & Walker, 2007), innovation purposes and strengthen economic growth (Kauppi & Kemppainen, 2008). Nowadays, there is increasingly more information and data available regarding all aspects of public procurement activity. This enables all individuals and entities involved to have a greater understanding of the business, as it helps them comprehend their position in the market relative to the competition and identify recent business opportunities, for example. The available data sources vary from country to country. In Spain, public companies can choose data sources from the national portal known as PLACSP (*Plataforma de Contratación del Sector Público*) or the portals based on their geographic region (Andalusia, Galicia, etc.).

As previously mentioned, and proven in some literature, the existence of some comparative urban indicators does not preclude the discovery of more discrete indicators that influence urban growth. However, despite the increasing study of public procurement activity, many authors have not yet considered this factor as one of the indicators to describe urban growth. However, there is a study made by Curado *et al.* (2021) which relates the use of USL methodology for the public procurement activity in the municipalities of Portugal. With that being said, in this study, we will apply the USL methodology for the public procurement data in Spain.

On the next chapter, this work will dig in even more about what is USL and the contexts of study that surround this subject, but also through related published works about public procurement data analysis and its impacts, and even articles about regional comparative studies. Chapter 3 will be all about the data collected and some context about it. Next, Chapter 4 will discuss the results from the data collected, starting with an analysis on the evolution of the scaling coefficients throughout the years at the regional and national level. Afterwards, it will step up to the deviations of each region using a method related with USL named Scaled Adjusted Indicatores which it will be used to compare the regions of Spain and see its evolution, along with the correlation of these results with some socio-economic indicators. Chapter 5 concludes this study with some final points alongside some limitations of the present work and future guidelines that could appear.

2. LITERATURE REVIEW

2.1. BACKGROUND

To initiate the study on the USL methodology and its potential applications, we will begin by reviewing the existing research and dissertations on the subject. This includes examining the scope and level of these studies, as well as the conclusions they have contributed respectively to the scientific community. Additionally, we will also see comparative studies conducted at the regional level that support the selection of regions in Spain as the focus of this research.

For a better understanding of the topic studied in this work, it is also necessary to have more details about published works regarding the topic of Public Procurement. Not only just to understand what Public Procurement is, but also its impact on some countries. Furthermore, there are some studies that were made regarding how the procurement data has been analyzed, which supports the discussion made in this thesis. These studies encompass several areas such as financial, ecological, and healthcare, all of them with interesting conclusions.

2.2. URBAN SCALING LAWS

USL is a topic of study with nearly 20 years of discussion, starting in the middle 2000 where many of these studies started to realize that larger cities concentrate more innovations, demonstrating higher complexity. These first studies reveal constraints on urban structure and evolution, linking city size, function, and innovation cycles within urban systems (Lobo *et al.*, 2006). The literature proves the existence of some typical behaviors when comparing socio-economic indicators with the size of the population: there can be superlinear indicators where the socioeconomic production in larger cities produce above the linear expected value; and also, the existence of sublinear indicators in contrary as it is the example of infrastructure variables where tend to be below the linear value that was expected for the dimension of the city (Miranda, 2015).

One of the first articles to appear is from Lobo *et al.* (2006) which analyses some important indicators in the French Urban Areas aligned with an evolutionary theory for interpreting USL from 1960 to 2000. Other studies focus more on the mathematical side of this methodology as it is the case of the study made by Chen & Zhou (2008) where he uses mathematical foundations and empirical evidence which supports the Self-Organized Criticality (SOC) in urban systems in China are based on the hierarchical structure of cities, formulated through exponential functions such as the number law, population size law and area law.

Despite these first studies on the USL focused on the data from cities agglomerations to support their empirical theory, some studies like the one from Cottineau *et al.* (2015) demonstrate that the meaning of what a city and what are its characteristics are challenged by varying scaling regimes based on city delineation criteria, impacting conclusions on city compositions. He *et al.* (2022) explores in his work within Wuhan at municipal and district scales, focusing on compact urban form development and spatial autocorrelation analysis.

Moreover, some studies already refer to the object of study just to existent regions instead of defined cities like for example the work of Khiali-Miab *et al.* (2019) where they combine the cities from Switzerland which were divided in NVPM zones to better understand personal incomes in metropolitan

areas in this country using the methodology of Urban Scaling aligned with Polycentricity. Finance & Swerts (2020) say scaling laws in urban geography are applicable across various regions, aiding in understanding urban structures, innovation diffusion, metropolization, and intra-urban dynamics.

There are many important studies concerning these matters, abording the scaling laws across different regions and urbanized areas around the world, reaching out the analysis to the most diverse indicators. Nonetheless, we can also highlight some articles in specific that contribute a lot to the study of USL: *Scaling Laws and the Modern City* by Isalgue *et al.* (2007) and *A unified theory of urban living* by Bettencourt & West (2010).

2.3. COMPARATIVE STUDIES

Despite the focus of this study is the application of the USL methodology in the public procurement data, it is also important to understand the context of comparing regions in specific socio-economic indicators. Comparative analysis at the regional level is essential for comprehending the dynamics within specific geographical areas. By comparing regions, researchers can uncover unique regional characteristics, identify commonalities, and understand differences in economic, social, cultural, and political dimensions. This approach facilitates the identification of regional patterns and trends, enabling policymakers and stakeholders to formulate targeted interventions and policies that address regional disparities effectively. Cho *et al.* (2023) compared open public data content managed by different government entities in Korea, highlighting higher usability for national-level specialized information over regional data.

Comparative studies at the regional level contribute to fostering regional cooperation and integration by promoting dialogue, sharing knowledge, and building partnerships among regions facing similar challenges. Additionally, comparative analysis at the regional level helps policymakers and stakeholders to learn from successful regional strategies and experiences. By examining outcomes across different regions, policymakers can identify best practices, innovative solutions, and lessons learned, which can inform decision-making processes and contribute to the development of effective regional development strategies (Abdel-Nazeer, 2022).

Looking at some comparative studies made in Spain, these also reveal significant differences across various dimensions. Financial knowledge determinants vary regionally, with factors like health status, financial fragility, birthplace, and age impacting regions differently (Oliver-Márquez, 2023). Additionally, demographic and economic indicators highlight inequalities between Spanish regions, such as varying fertility rates, foreigner proportions, and economic disparities (Sanchís & Teresa, 2019).

2.4. PUBLIC PROCUREMENT

Now that we have a better context on USL and Comparative Studies, it is necessary to have some background on what it is Public Procurement, what are its objectives and in what related studies this subject has been considered.

Public procurement refers to the process by which governments and other public sector entities purchase goods, services, or works from external suppliers (Kikavets, 2023) following a set of predefined rules, regulations, and procedures. It involves the acquisition of goods, services, or works by public entities, such as government agencies, municipalities, public corporations, and other public institutions, using public funds. Public procurement is typically governed by specific laws and

regulations that aim to ensure fairness, transparency, and accountability in the procurement process (Nowicki, 2022).

Public procurement can encompass a wide range of goods, services, and works, including construction projects, IT equipment, consulting services, medical supplies, transportation services, and many others. It involves various stages, such as planning, tendering, contracting, and contract management, and may involve competitive bidding, negotiation, and other procurement methods depending on the specific rules and regulations of the jurisdiction (Douh, 2016).

The objectives of public procurement may vary, but typically include obtaining value for money, promoting competition, ensuring transparency and accountability, supporting socioeconomic development, and achieving public policy goals, such as environmental sustainability, social responsibility, and innovation (Treviño-Lozano, 2022). Public procurement is a critical function of government, as it involves the expenditure of public funds and plays a significant role in the delivery of public goods and services to citizens (Kokocińska, 2023).

Public procurement in Spain is subject to a legal framework that regulates the procedures and rules for awarding public contracts. The main legislation governing public procurement in Spain is the Public Sector Contracts Law (*Ley de Contratos del Sector Público*), which sets out the principles and procedures for procurement activities carried out by public sector bodies at the national, regional, and local levels. Public procurement in Spain is a significant economic activity, accounting for a substantial portion of government spending.

2.5. PUBLIC PROCUREMENT DATA ANALYSIS

When it comes to the public procurement data analysis, this refers to the process of examining and interpreting data related to public procurement activities (Sousa *et al.*, 2023). Analyzing public procurement data can provide valuable insights into government spending patterns, contract awards, supplier performance, and overall procurement efficiency. It enables governments and organizations to detect potential irregularities or corruption, enhance transparency, improve decision-making and identify trends in the procurement process like in the study of Lyra et. al (2021).

Moreover, in most papers regarding the detection of fraud behaviors, they propose a graph-based method called PANG. In the paper *Pattern Mining for Anomaly Detection in Graphs: Application to Fraud in Public Procurement* (Figueiredo *et al.* 2023), it identifies subgraph patterns that are characteristic of fraud-prone situations, allowing for a better understanding of fraudulent behavior in public procurement. The experiments conducted in the paper also reveal that induced patterns are more discriminative on certain datasets, further highlighting the effectiveness of the PANG framework.

In recent years, there have been efforts to improve transparency and efficiency in public procurement not just in Spain but also around the globe, with the aim of reducing corruption and ensuring that public resources are used effectively. In the study *High Earnings Through Firm Influence: The Role of Hierarchical Structures in Public Procurement.* (Strum *et al.*, 2024) the research highlights the need for reforms to promote fairness, competition, and efficiency in public procurement, which are crucial for optimizing public spending and fostering economic growth. Nonetheless, there is still a lot of work to be done as was shown in the Barcelona Metropolitan Area (Fazekas & Kocsis, 2017) where tools like codes of ethics, conflict of interest declarations and basic standards of publication are

underused by the entities. Other tools include the adoption of electronic procurement systems, the introduction of new rules on contract award criteria, and the establishment of a centralized platform for public procurement information.

As already mentioned before, another important topic related in public procurement data analysis is the predictive analysis, most of them to predict corrupt contracts like in the *A machine learning model to identify corruption in México's public procurement contracts* (Aldana *et al.*, 2022) where the paper proposes a machine learning model called hyper-forest to identify corrupt contracts based on the relationship between buyers and suppliers in Mexico. In Slovakia, a study was made to examine the effect of the data structure enhancement on prediction performance by focusing on the quality assurance of data structure in AI driven procurement decision making, determining that the quality of the data structure is crucial for an accurate prediction performance (Delina & Macik, 2023). In a systematic literature review on data-driven methods for detecting fraud, corruption, and collusion in public procurement processes, machine learning and network science, show promise in detecting fraud, corruption, and collusion in public procurement activities (Puspitasari, 2023).

These predictive models can also enhance the public procurement efficiency by providing insights into supplier involvement (Tsyganova *et al.* 2023) which allows to increase competition among the suppliers' participants (Muxiddinovich, 2023). Additionally, scientific conclusions and recommendations for radical reforms in public procurement can lead to more effective organization and targeted use of state budget funds, further improving efficiency (Lyra *et al.*, 2022).

3. DATA AND METHODOLOGY

3.1. URBAN SCALING LAWS

From a mathematical perspective, USL measures the relationship between a certain indicator, *Y*, and a certain population size, *X*, of a set of population agglomerates like cities or even regions as a power-law, such as:

$$Y \approx \alpha X^{\beta}$$

where the β is the scaling factor of the population size and α represents the natural baseline activity of an agglomerate (Isalgue *et al.*, 2006). While some indicators such as housing and jobs (Arcaute *et al.* 2013) follow a linear relationship (β = 1), the cases that are more interesting to study are those in which Y exhibits a scaling coefficient different than 1, either having super-linear (β > 1) or sub-linear (β < 1) behaviors. Such cases identify indicators that either scale above (super-linear) or below (sub-linear) linear growth with increasing population size, respectively. Super-linear behavior is often observed in indicators like economic output (Lobo *et al.*, 2013; Bettencourt, 2013; Balland *et al.*, 2018), energy consumption (Barkhordar, 2022), criminality (Alves *et al.*, 2022; Lobo *et al.*, 2013), number of patents (Lobo *et al.*, 2013; Bettencourt *et al.*, 2007; Bettencourt & Lobo, 2016), salaries (Bettencourt *et al.* 2007) and urbanized area (Bettencourt & Lobo, 2016). On the other hand, sub-linear relationships can be seen in the total length of road network (Bettencourt, 2013; Bettencourt *et al.*, 2007; Lämmer, 2006) and in energy supply networks (Kühnert, 2006). In sum, population agglomerates present clear trade-offs between human activity outputs that increase from agglomeration and infrastructure costs that reduce with agglomeration.

As it was shown in the Literature Review, in most of the articles collected, they studied some of these indicators at a municipality context (Batty, 2008), while some few show that it remains an open question to in which conditions can be considered an appropriate population aggregation unit (Cottineau *et al.*, 2015; He *et al.*, 2022; Cottineau *et al.*, 2017). Since the contracts collected in the data presents their execution place to the level of provinces and not municipalities (as it will be shown in the next chapters), we apply this model to the province level.

3.2. REGIONAL ORGANIZATION

Before going in detail to the data collected, it will be presented in this section an overview on Spain's geographical organization and its alternative divisions that could have been chosen, as this country is divided into several levels of administrative and regional organization. The regional organization of Spain is characterized by a high degree of decentralization, meaning that the country is divided into multiple autonomous communities, each with its own level of self-governance and varying degrees of legislative, executive, and administrative powers. This system of regional organization is primarily designed to accommodate Spain's diverse cultural, linguistic, and historical differences.

Spain is divided into a total of 17 autonomous communities which are the primary regional divisions of Spain, each with its own government, parliament, and administration. The degree of autonomy varies among the different communities, but most of them have their own education,

health, transportation, and cultural policies. Autonomous communities have the authority to manage many aspects of their own affairs, while still adhering to the overall laws and constitution of Spain.

These Autonomous Communities can be grouped into 7 big clusters: Northwest (ES1, *Noroeste*), Northeast (ES2, *Noreste*), Community of Madrid (ES3, *Comunidad de Madrid*), Center (ES4, *Centro*), East (ES5, *Este*), South (ES6, *Sur*) and Canary Islands (ES7, *Canarias*) which group autonomous communities with similar geographical and socio-economical characteristics.

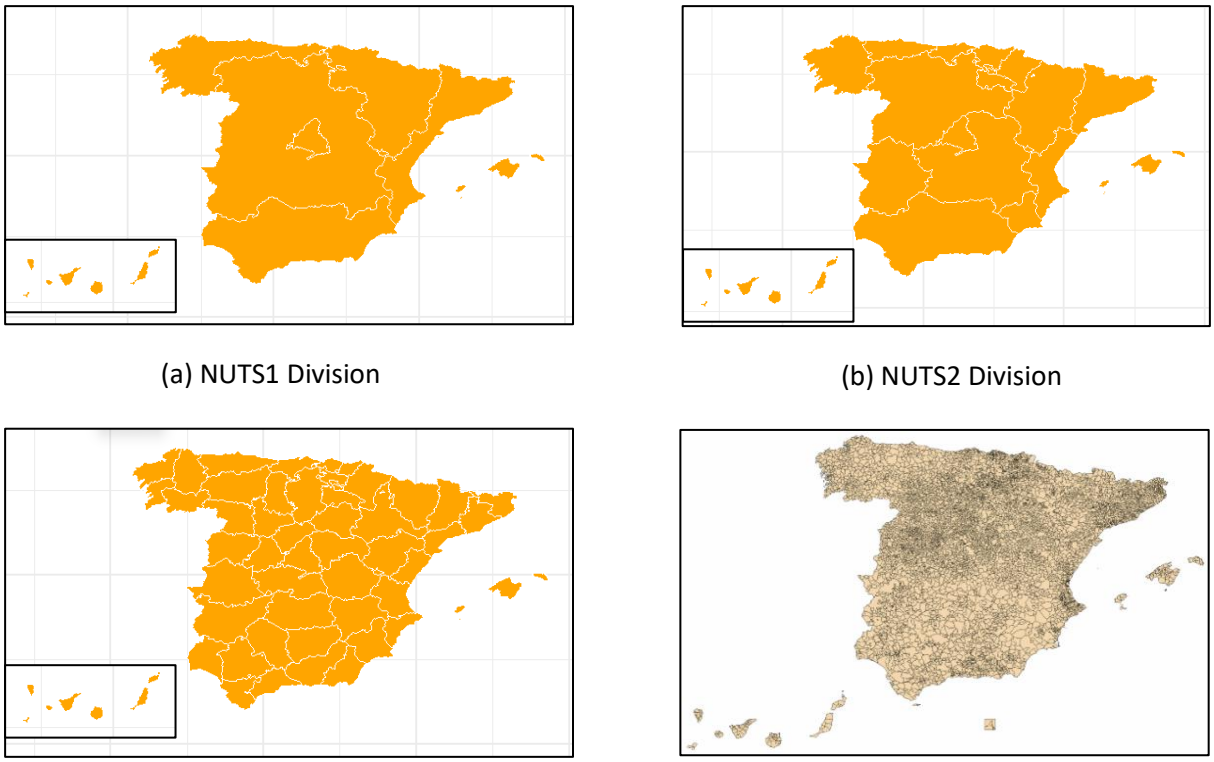
Each autonomous community is further divided into provinces. Provinces are administrative divisions responsible for implementing national and regional policies within their territories. There are 59 provinces in total, and they serve as intermediaries between the central government and the local municipalities.

Municipalities are the smallest administrative units in Spain. There are more than 8000 municipalities, and they are responsible for providing local services such as education, health care, waste management, and local infrastructure. Each municipality has its own local government headed by a mayor or similar administrative head.

For this study we will focus our analysis on the province level, which as the evidence supports, there are many disparities at the various levels like, for example, economic disparities among the autonomous communities. Regions like Madrid, Catalonia, and the Basque Country have strong economies, with high GDP *per capita* driven by sectors such as finance, technology, and manufacturing. On the other hand, regions like Extremadura, Murcia, and Andalucia have lower GDP *per capita* and higher unemployment rates, with economies more reliant on agriculture, tourism, and low-skilled industries.

These regions also present some differences in the government structure, with the different communities presenting different levels of autonomy, where regions like Catalonia, the Basque Country, Galicia, and Andalucia have a higher degree of autonomy which includes control over areas such as education, healthcare, and transportation. On the other hand, regions like Murcia or Extremadura have fewer powers and are more reliant on the central government. This autonomy is also associated with fiscal autonomy where some autonomous have a special fiscal relationship with the central government, allowing them to collect and manage their taxes independently which allows them to have greater control over their finances and economic policies.

In another perspective, in most recent years, another divisional territory has been presented – the European Nomenclature of Territorial Units for Statistics (NUTS) which was developed by Eurostat and applied to the all the countries of the European Union for statistical purposes. For Spain, the subdivisions of the different levels represent almost the descriptions of the division mentioned above. NUTS I represent groups of autonomous communities; NUTS II represent the autonomous communities and autonomous cities and NUTS III represent the provinces and the islands. The Municipalities are inserted into a lower level called Local Administrative Units (LAU) which will not be covered in this study.



(a) NUTS1 Division

(b) NUTS2 Division

(c) NUTS3 Division

(d) Municipal Division

Figure 3.1 – Regional Divisions in Spain

3.3. DATA COLLECTED

Due to the geographical organization presented, public procurement data in Spain is spread across different public portals and online platforms, meaning, public contracts can be submitted in one or more portal. The most used is *Plataforma de Contratación del Sector Público* (PLACSP) which is the official national platform used for Public Procurement in Spain. Other portals can be used across the different autonomous communities, such as *Contractació Pública de Catalunya* (Catalonia), *Euskadi Contratación* (Basque Country).

To focus this analysis, it was used a dataset with only data from PLACSP, to avoid having a big number of duplicates. It was collected data comprising contracts from January 2012 and until December 2022. For each contract, it was collected the following information: the date in which the contract was celebrated, the value of the contract, the type of contract, the CPV, the location of contract's celebration, the identity of the buyer and supplier (name and Fiscal ID), and the value issued for each supplier (in the case the contract was celebrated in lots).

As it was already mentioned in the previous chapter, there are several geographical divisions that can represent Spain as a country. As many of these contracts have the information of where the contract was celebrated only represented to the level of Provinces at least, ignoring the level of Municipality, it will only be considered the contracts celebrated on this level.

As so, it were excluded all the contracts celebrated outside Spain and moreover, those contracts which have the country as the place of execution, i.e., instead of appearing the respective Province, it appears Spain as the place of execution of the contract. This information has limited the dataset in the first years of the study (from 2012 to 2016) as the big majority of these contracts had Spain as their place of execution.

There were some contracts also executed in the level of the Autonomous Communities in which there were two different treatments for these contracts. On one hand, the contracts celebrated in Autonomous Communities that enclose more than one province, they were also excluded from the dataset, giving the same logic treatment that was giving at the contracts celebrated at a national level. On the other hand, the contracts celebrated in Autonomous Communities that only have one Province associated with them, they were grouped with the contracts to the respective province. These autonomous communities are Principality of Asturias, Cantabria, Navarre, La Rioja, Madrid, Murcia, Ceuta and Melilla.

To finish the pre-processing of the data, there were also removed contract with a value below 1€.

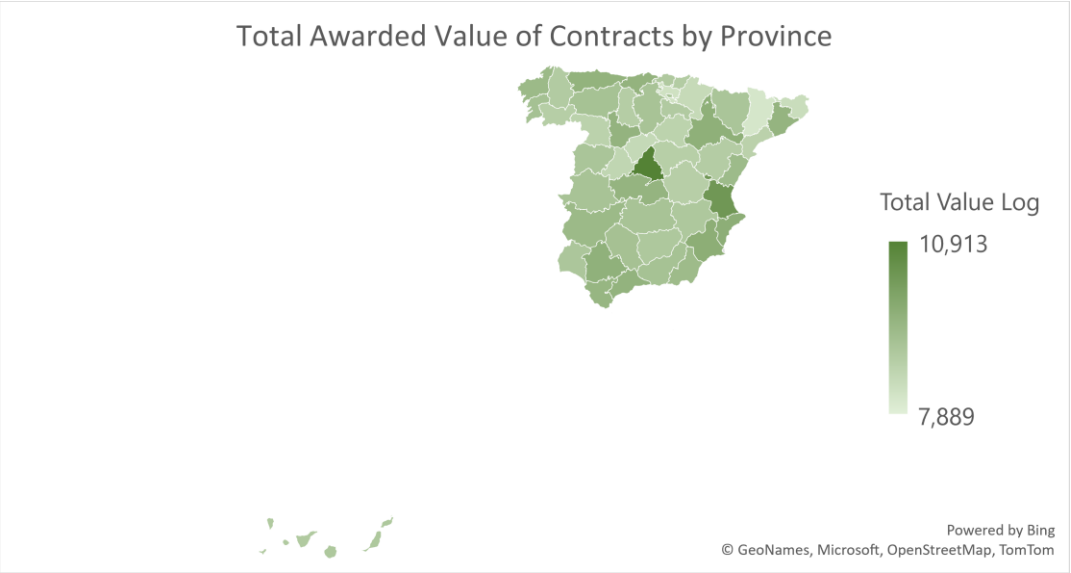


Figure 3.2 – Spatial distribution of the total number of contracts awarded and the total value of those contracts.

The final dataset contains 401.767 contracts from January 2017 to December 2022, summing a total amount of 194 billion Euros worth of contracts.

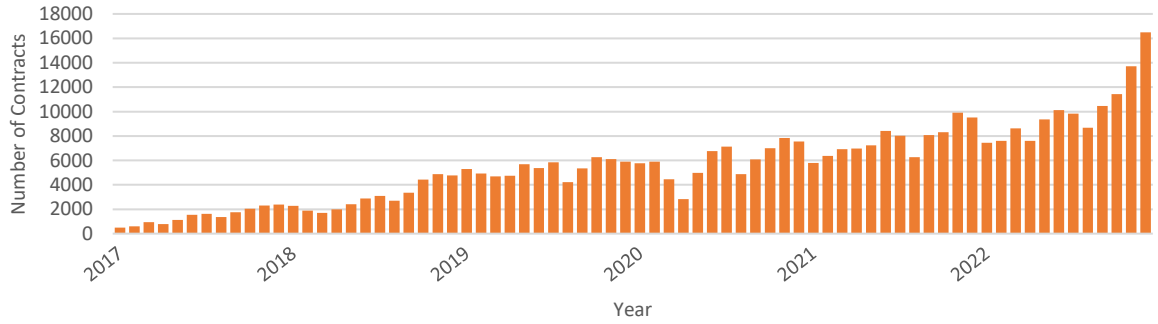


Figure 3.3 – Number of Contracts formalized in each month from January 2017 to December 2022

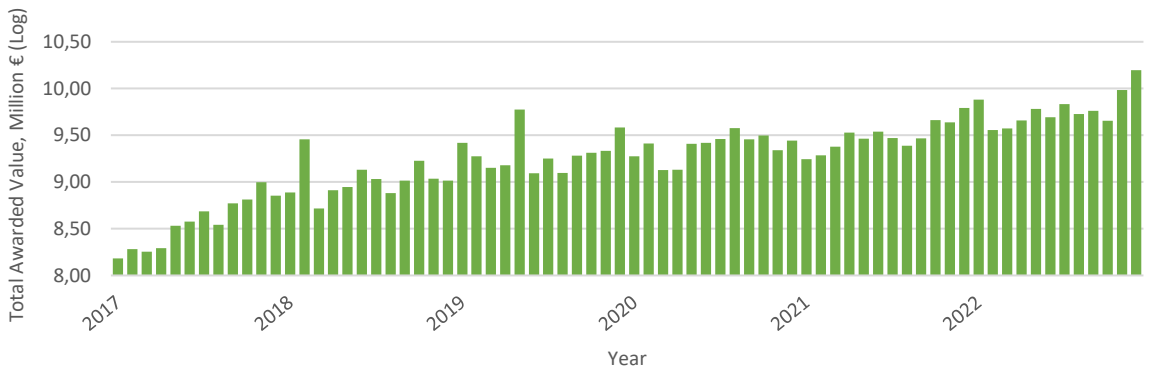


Figure 3.4 – Total Awarded Value of the Contracts formalized in each month from January 2017 to December 2022

As we can see, there are some high values in the months of May of 2019 and December 2022 which may reflect an investment by the provinces before the respective elections in November 2019 and June 2023.

For the final dataset we organized this data with the contracts as row and their properties organized in the columns from which it is possible to highlight:

- Contract Start Date – The date where the contract took place
- Execution Place – The location where the contract took place, designated by the NUTS 3 code
- Contract Value – The value of the contract, in euros
- Type of Contract – The main category of the contract

Furthermore, it was collected some data from Eurostat (Eurostat, 2024) on multiple socio-economic indicators by year for each region, both on the level of NUTS 2 (Autonomous Community) and NUTS 3 (Province). It was collected the following indicators: Agriculture Income, Air Transport Passengers, Employees, GDP, Hospital Beds, Income of Households, Long Term Unemployment, Number of Households, Number of Vehicles, Road Accidents, Tech Employees, Total Births, Total Transported Goods and Volume of Tourism.

Table 3.1 – Socio-Economic Variables description

DATASET	YEARS	MISSING VALUES	UNIT	MEAN	STD DEV	MIN	MAX	NUTS
Agriculture Income	2017-2021	10	Million Euros	3 102,37	3 299,67	219,59	14 555,28	NUTS2
Air Transport Passengers	2017-2022	25	Thousand Passengers	13 304	17 449	67	59 747	NUTS2
Employees	2017-2022	0	Thousand persons	1046,73	1094,11	28,60	3678,20	NUTS2
GDP	2017-2022	0	Million Euros	63970,98	69869,94	1514,54	261713,10	NUTS2
Hospital Beds	2017-2021	0	Nº	7335,55	7286,78	161,00	29375,00	NUTS2
Income of Households	2017-2021	0	Million Euros	40 796,72	44 785,38	1 028,7	158 808,	NUTS2
Long Term Unemployment	2017-2022	0	Thousand persons	72,01	84,5	4,2	432,8	NUTS2
Number of Households	2017-2022	0	Thousands of Households	986,6	976,7	23,2	3 337,4	NUTS2
Number of Vehicles	2017-2022	0	Nº	1 588 785	1 540 987	49 183	5 341 511	NUTS2
Road Accidents	2017-2022	3	Nº	1 622	3 045	1	20 986	NUTS3
Tech Employees	2017-2022	12	Thousand persons	45,01	66,35	1,50	282,50	NUTS2
Total Births	2017-2022	0	Nº	6 008	9 191	48	60 555	NUTS3
Total Transported Goods	2017-2022	0	Thousand Tones	24276,58	25132,32	19,00	137883,00	NUTS3
Volume of Tourism	2017-2022	0	Nr of Accommodations	19858208,09	27167449,96	58895,00	104382580,00	NUTS2

3.3.1. Common Procurement Vocabulary

Despite the study is meant to understand the differences between the public investment in the provinces of Spain, it is important to acknowledge that these contracts can be split by types of contracts. There are three main types of contracts: Works, Goods or Services Contracts. These three categories encompass most procurement activities conducted by these public sector entities.

The Works contracts involve the execution, design, or construction of civil engineering or building works (such as construction, renovation, demolition, etc.). Services contracts are classified as services that involve the provision of services rather than the supply of goods or the execution of works. This category encompasses a wide range of activities, including consulting, professional services, transportation, among others. Finally, Goods type of contracts involve the acquisition, purchase, or delivery of goods, products, or commodities.

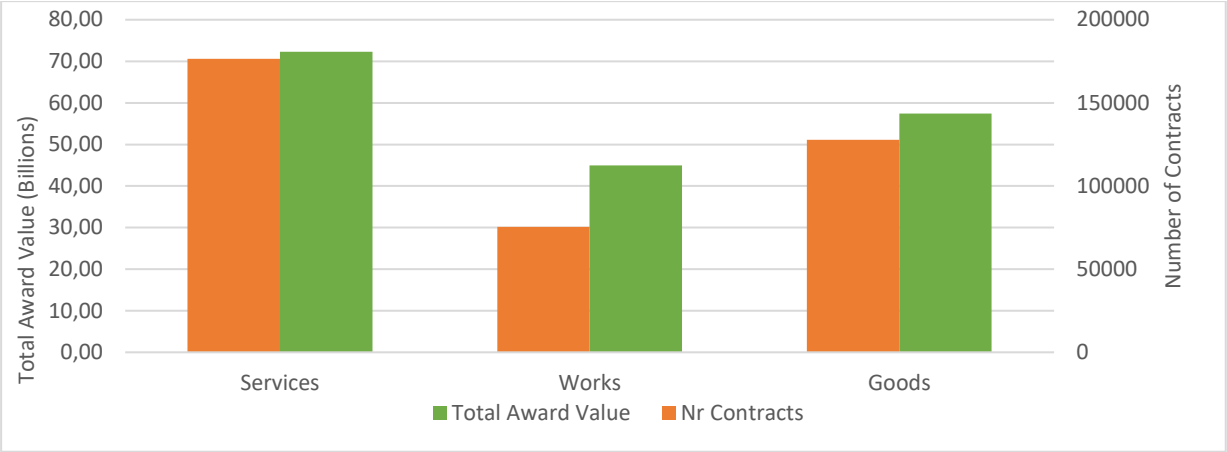


Figure 3.5 – Distribution of the number of contracts and total award value by type of contract

As it is possible to see in Figure 3.5, the Services type of contract has the most contracts realized, with nearly 175.000 contracts awarded, corresponding to a higher awarded value among the three main types of contracts with more than 70 billion euros awarded. Goods contracts represent the second type of contract followed by the Works contracts.

Furthermore, each procurement contract is also classified following the Common Procurement Vocabulary (CPV), an established classification mechanism employed throughout the European Union (EU) for the organization and description of contracts in public procurement. With the CPV classification, contracts can have a standardized classification that is valid across all the EU for all the procedures occurring here.

The CPV system is hierarchical, organized into a structure of codes and sub-codes, with each level representing a more specific classification. Each code and respective subcodes represents an industry, a type of product, or a type of service, which allows the contracting authorities to classify better their procedures. It was conducted an analysis on the number of procurements and their total awarded value by CPV but since there are thousands of CPV codes, and each contract can have more than one CPV code associated with, for this study we will only focus our analysis on the three main types of contracts – works, services and goods contracts.

4. RESULTS AND DISCUSSION

To start the analysis of the procurement data collected, this chapter starts by analyzing the scaling coefficients of the public procurement data.

The graphic in Figure 4.1 represents the scaling behavior from the year 2022, which is already divided by colors where each color represents a group of autonomous communities where the province is inserted in. From this graphic we can highlight some interesting conclusions. Here, we can see the effect that many provinces from the autonomous community of Catalonia have, which might represent the hypothesis of some regions only consider their regional portals to register their contracts. It is also possible to notice that the region of the Community of Madrid (ES3) registered the highest total awarded value, which might indicate already a centralization of the national economy, for both public and private institutions. Nonetheless, in this year of 2022, the procurement activity showed a sub linear scaling behavior, with a scaling coefficient $\beta \approx 0{,}86$.

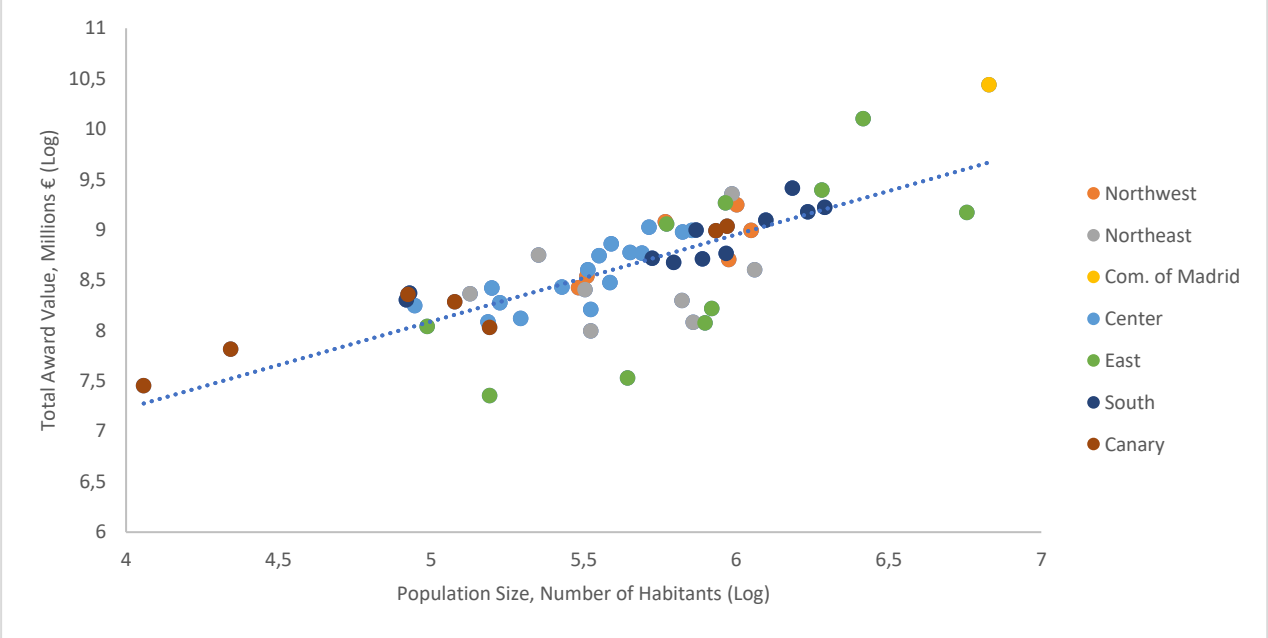


Figure 4.1 – Relationship between Total Awarded Value and Population Size in 2022

If we analyze furthermore into the different types of contracts – goods, services and works – in 2022 all these 3 types of contracts presented a sublinear scaling behavior, with more emphasis in the Works contract. As a matter of fact, both Goods and Services presented values in 2022 very close to a linear scaling behavior, with a scaling coefficient around 0,95. Looking at the regional level, we can identify that most provinces presented similar behavior across the 3 types of contracts.

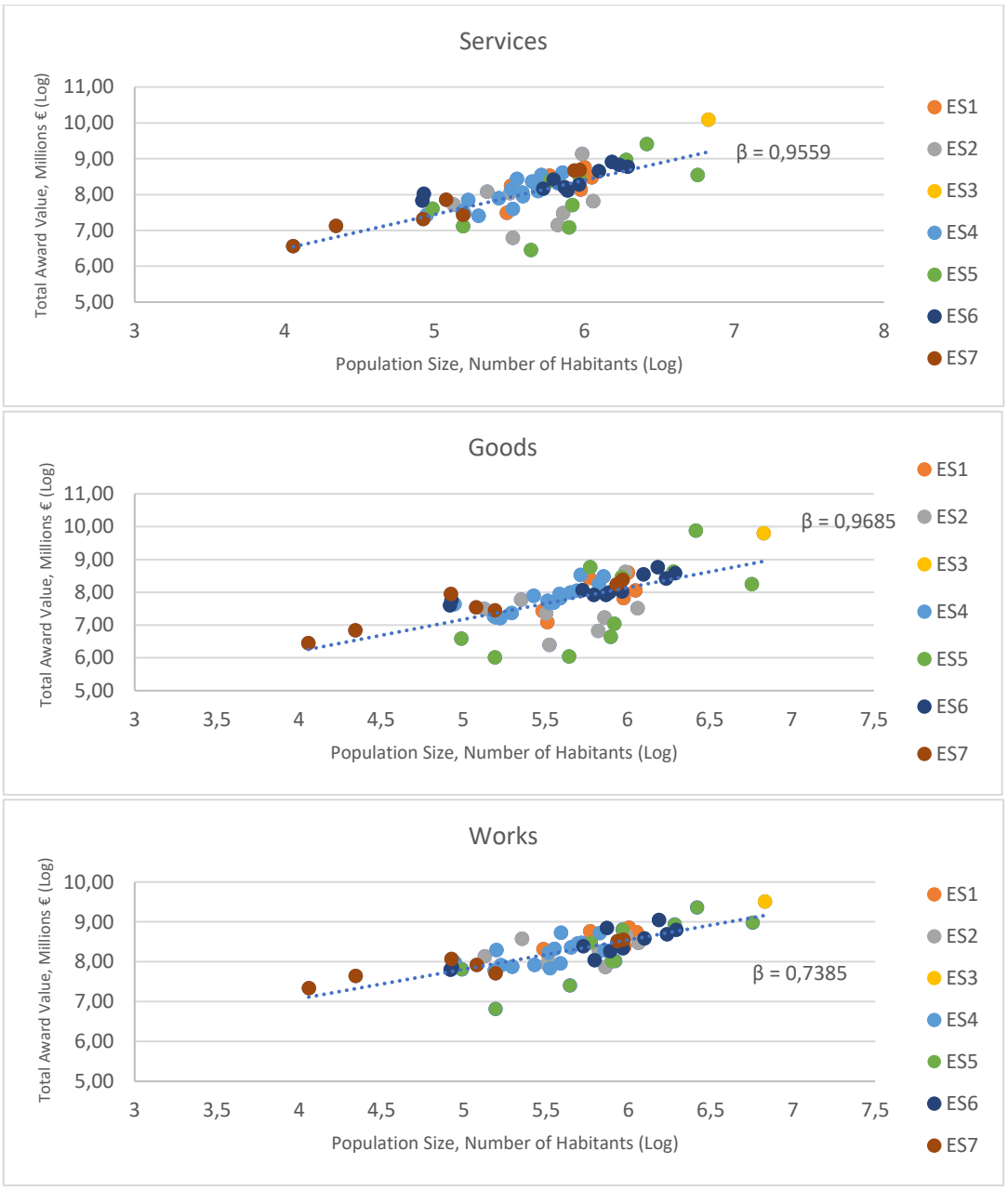


Figure 4.2 – Relationship between Total Awarded Value by Type of Contract and Population Size in 2022

For the result obtained for the total procurement, we can see in Figure 4.3 that, between the period of 2017 to 2022, it presents a descending trend, going from having a linear behavior in 2017 to a sub linear in the following years. In these following years, the scaling behavior has presented a stable value of a scaling coefficient around 0,80, with in the last years starting to have an upward trend of these values. The value observed in 2017 might be explained by the quality of the data in this year as it was explained that the years prior to 2017 (inclusive) had a low number of contracts in the national portal, as well many contracts having the place of execution as Spain (ES), which is the designation of the country.

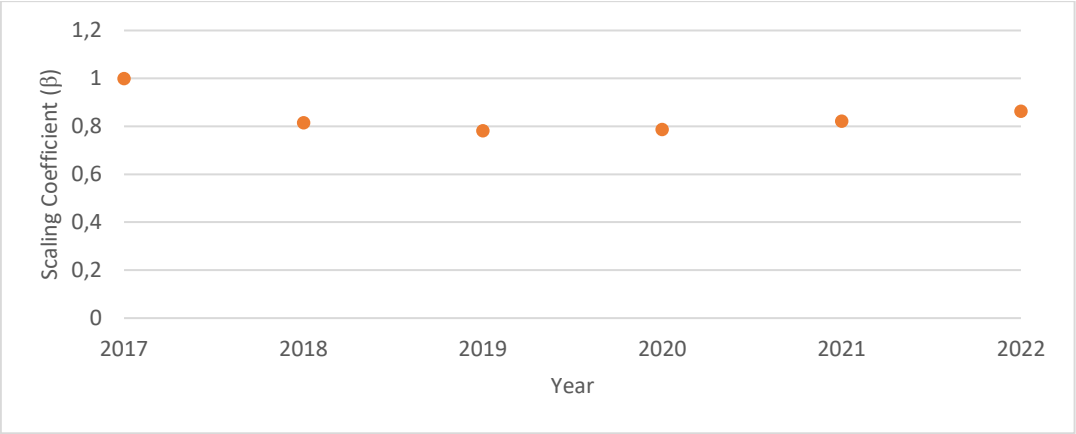
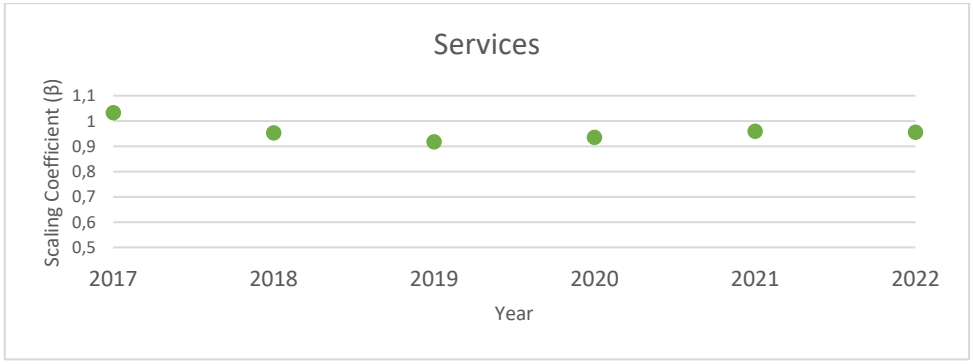
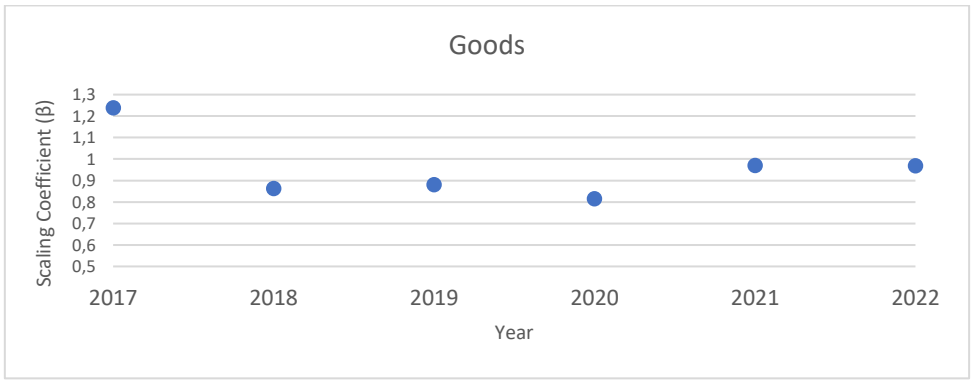


Figure 4.3 – Scaling Coefficient (β) of the Total Procurement Activity between 2017 and 2022.

When analyzing the time evolution of the scaling by type of contract –we noticed that like the procurement activity data in general, in 2017 it presented a peak in all three types of contracts, which was followed by a descending trend. After the year 2017, all three types of contracts showed sub-linear scaling behavior, with more impact in the Works contracts. Moreover, these three types of contracts have presented an increasing pattern in their behavior, with Goods and Services contracts almost reaching a linear behavior, with very few fluctuations, meaning that there was a consistent evolution towards a linear behavior.





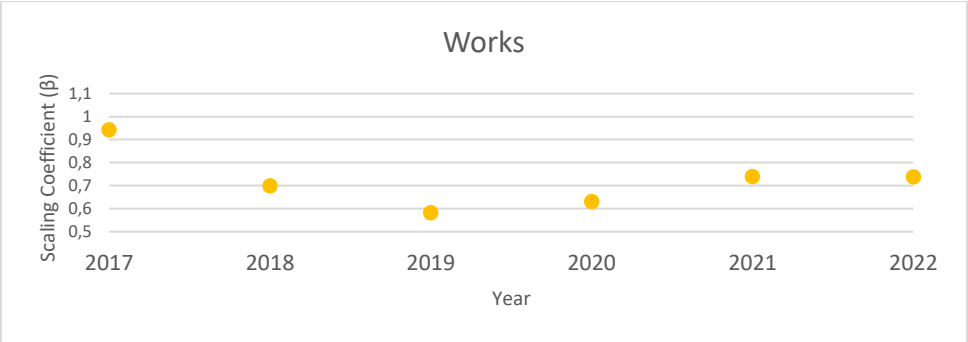


Figure 4.4 – Scaling Coefficient (β) of the Total Procurement Activity by Type of Contract between 2017 and 2022.

4.1. Scale-Adjusted Indicators

Comparing urban data related to the dimension of the population or the city can be a challenge to this analysis, since comparing certain indicators in large and small cities/regions directly without adjusting for population size can be misleading. This scaling assumption occurs if the indicator has a linear scaling behavior with the population size. One method that the literature on USL proposes is the use of the residuals of each region to work as the reference model, instead of the value of all regions in general. For this study, the residuals indicate if a region is spending more or less than the expected value according to its population size.

For that reason, it will be used the Scale-Adjusted Indicators (SAI). SAI are metrics that correct for biases in urban data analysis caused by nonlinear relationships between urban indicators and population size (Levine *et al.*, 2021). These indicators provide a more accurate representation of urban evolution by comparing actual values with those expected based on population scaling laws. Additionally, scale-adjusted metrics exhibit strong correlations with past values and among themselves, allowing for effective forecasting of future urban indicator values (Alves *et al.*, 2015).

To calculate this value, it is used the following formula:

$$SAI_{i,t} = log_{10} Y_{i,t} - log_{10} Y(N_{i,t})$$

where $Y_{i,t}$ is the actual observed expenditure of the municipality i on the year t, and $Y(N_{i,t})$ is the predicted expenditure for the municipality according to its population size.

4.2. Procurement Activity and Socio-Economic and Demographic Indicators

Looking closely at the scaling coefficients of each socio-economic indicator collected, we noticed that the majority of are in line with the articles and papers collected, with some of these indicators presenting a super linear behavior as it is the case of Tech Employes (β ≈ 1,25 ± 0,031), Volume of Tourism (β ≈ 1,24 ± 0,026), Road Accidents (β ≈ 1,16 ± 0,047), Total Transported Goods (β ≈ 1,14 ± 0,039), Air Transport Passengers (β ≈ 1,13 ± 0,053), Hospital Beds (β ≈ 1,08 ± 0,077), GDP (β ≈ 1,04 ± 0,004), Number of Households (β ≈ 1,04 ± 0,003), Total Births (β ≈ 1,04 ± 0,007), Income of Households (β ≈ 1,04 ± 0,002) and Employees (β ≈ 1,03 ± 0,003). On the other hand, there are some indicators with a sub linear pattern as it happens with Long Term Unemployment (β ≈ 0,88 ± 0,03) and the Agriculture Income (β ≈ 0,61 ± 0,004).

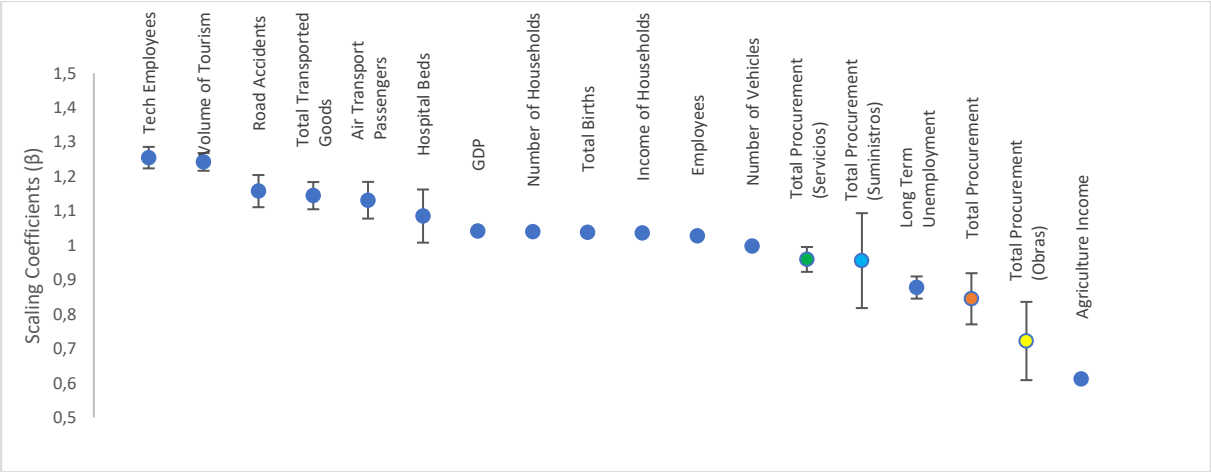


Figure 4.5 – Average Scaling Coefficients of Socio-Economic Indicators.

This study started by comparing the public procurement scaling coefficients, both in general and in the three main types of contracts with the socio-economic indicators that are commonly used to characterize the purchasing power of the region. To strengthen this analysis, it was estimated the Pearson correlation between the SAI of the public procurement activity by the three main types of contracts (Services, Goods and Works) with the SAI of the socio-economic indicators collected.

Figure 4.6 – Correlation between the SAI of the Public Procurement Activity and Socio-Economic Activity [1]

In Figure 4.6, it is possible to see the yearly correlation between the SAI of some of the socio-economic indicators and the SAI of public procurement activity. In all the charts collected, the vertical

[1] You can find the remaining charts in the Appendix B.

axis represents the Pearson Correlation while the horizontal axis indicates the year corresponding to the collected value. Here, it is possible to see in each chart three lines representing the main types of contracts – Services, Goods and Works. Looking at each indicator individually, we see that most of them have the three types of contracts either with a positive correlation or a negative one, all of them presenting values between approximately -0,5 and 0,5.

The indicators with a positive correlation with the SAI of public procurement are the following: Number of Vehicles, Air Passengers, Long Term Unemployment and Total Transported Goods. On the other, the indicators that have a negative correlation with the SAI of procurement activity are the GDP, Hospital Beds, Employees, Income of Households, Number of Household (despite positive values in Works contracts in 2018 and 2020) and Life Births. Nonetheless, the remaining indicators – Volume of Tourism, Tech Employes, Agriculture Income and Road Accidents – have presented some fluctuations with yearly changes in the correlation values, but generally keeping the consistency among the three main types of contracts.

As it is possible to see, there are some links between public procurement activity and socio-economic indicators, meaning that some of these indicators can be used to explain some behaviors of the procurement values, as well as potentially expand the control and understanding of the evolution of public procurement policies.

4.3. Comparing Regions by the SAI

As it was already mentioned, one good application of the SAI is to be able to compare different regions with different population sizes, as this methodology already corrects for population differences, so it can be easy to analyze which region are in this specific case spending more or spending less in public activity to what it is expected for their capacity. In Figure 4.7, there is a ranking of the average SAI of the results collected in each year for the public procurement activity with some provinces highlighted among which the 3 most populated ones.

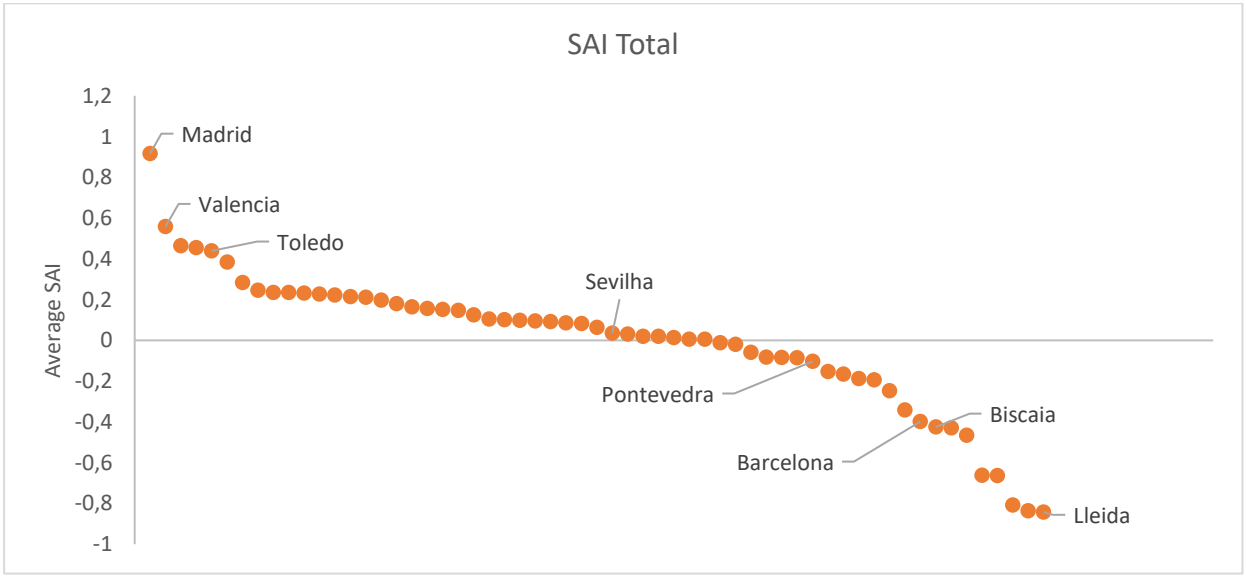


Figure 4.7 – Ranking of Provinces using the Average SAI between 2017 and 2022

As it is possible to see in Figure 4.7, some of the most populated regions such as the province of Barcelona and Bizkaia have negative SAI. Despite more evidence are required to came to a more certain conclusion, this result might also be connected to the fact that these provinces have their regional portals to publish their procedures rather than using the national portal, which may be a factor on why they have a negative overall SAI.

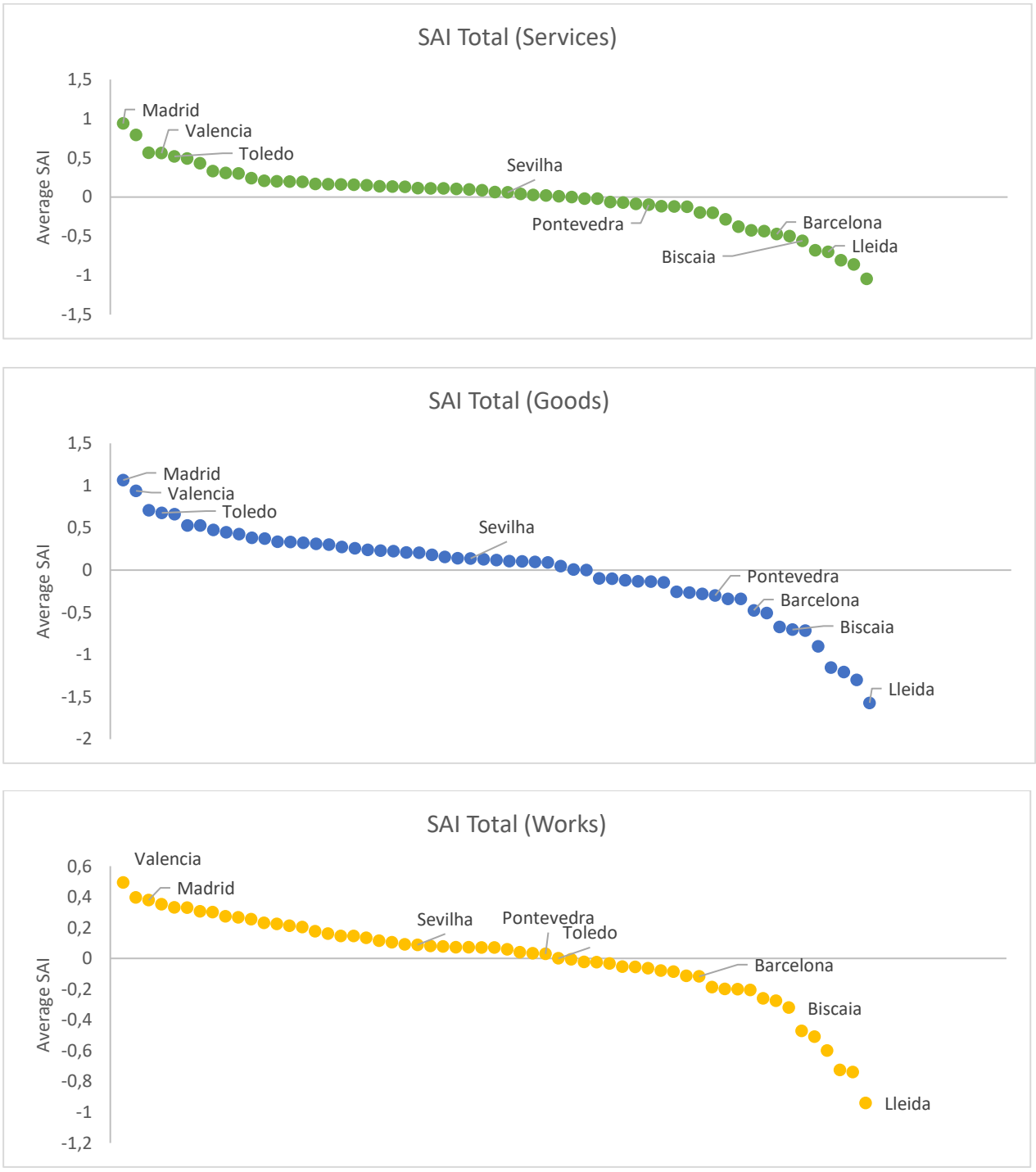


Figure 4.8 – Ranking of Provinces using the Average SAI between 2017 and 2022

Looking at each type of contract separately in Figure 4.8, we can check that most of regions highlighted in the graph of Figure 4.7 have either a positive or a negative SAI in the three types of contracts. However, there are some regions where in some types of contracts they present a positive SAI and in another a negative SAI. These results can potentially demonstrate the characteristics and the profile of each region.

4.4. Regional Divide

Each region of Spain presents unique characteristics, as we seen not just on the literature but also along the way the data was presented, which may determine and help us understand why some regions are more efficient than others on the way they are spending their money in public activities. With the Scale-Adjusted Indicators, it can help identify more easily those differences and singularities and potentially boost the regional development of certain provinces.

To gather similar regions/provinces among themselves, and as each autonomous community has their different levels of governmental autonomy and different economic status, we can group the provinces with similar characteristics not just by the level of autonomous communities but also by the group of Autonomous Communities, which is defined to the equivalent of the NUTS I, as mentioned in the chapter 3.2. Each one of these regions is composed by the provinces starting with number of associated to the number of the group of autonomous communities. As the Community of Madrid is only composed of one province, it will be considered for this region the data collected as a whole.

Looking at the average of the scaling coefficient of each cluster in Figure 4.9, it seems a little bit complicated to get some conclusions based on what was already mentioned in the previous data and in the supporting literature. However, it is possible to highlight that the clusters from the North side of the country present very different scaling coefficients ($\beta_{ES1} \approx 1{,}17 \pm 0{,}47$ and $\beta_{ES2} \approx 0{,}30 \pm 0{,}45$) but very similar deviations from their averages. Once again, it would require a bigger analysis on this set of data, but it might come from the fact of the existence of several regional portals, thus causing a lack of quality data for these regions.

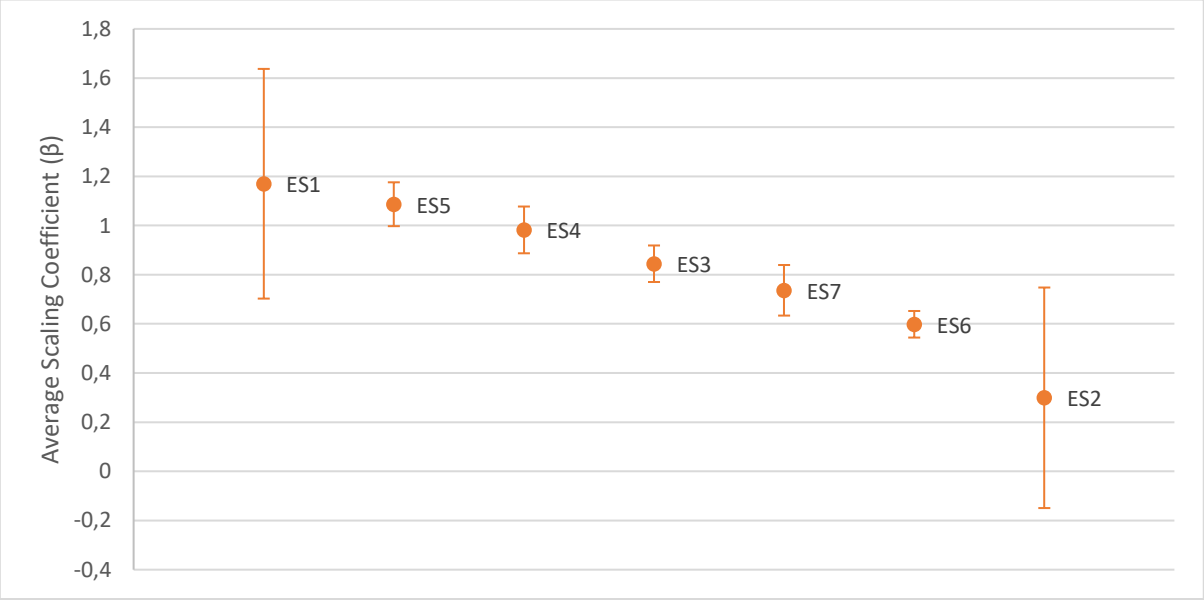


Figure 4.9 – Average Scaling Coefficients by Groups of Autonomous Regions

All other clusters have a more stable scaling coefficient ($\beta_{ES5} \approx 1,09 \pm 0,09$, $\beta_{ES4} \approx 0,98 \pm 0,10$, $\beta_{ES7} \approx 0,74 \pm 0,10$ and $\beta_{ES6} \approx 0,60 \pm 0,05$), but once again it seems a little bit difficult to take serious and robust conclusions on what is impacting the value of each region.

Even when analyzing these same values by type of contract, we get similar patterns, with each cluster in a similar position in the ranking and with very similar deviations from the average of the scaling behavior for that type of contract.

If we look at the average SAI of each group of regions by year represented in Figure 4.10, we can see some clusters with a positive SAI while others with a negative SAI. The first result that is highlighted is the highly positive SAI of the Community of Madrid (ES3), averaging a SAI of 0,92 across the timespan of this study. This value might be directly related to the fact of this region being the centralized point of all economy and administrative power of Spain.

Another important takeaway from this chart is that the group of regions Northeast (ES2) and East (ES5) throughout the years have presented a negative SAI, both with average SAIs near -0,20 for these regions which can be another argument for these regions to use their regional portals, as it can also mean a better and more efficient use of public funds in public procurement. Finally, it is important to mention that regions like Center (ES4), South (ES6) presented a positive SAI throughout the years, while Northwest (ES1) and Canary Island (ES7) were oscillating from negative and positive SAI.

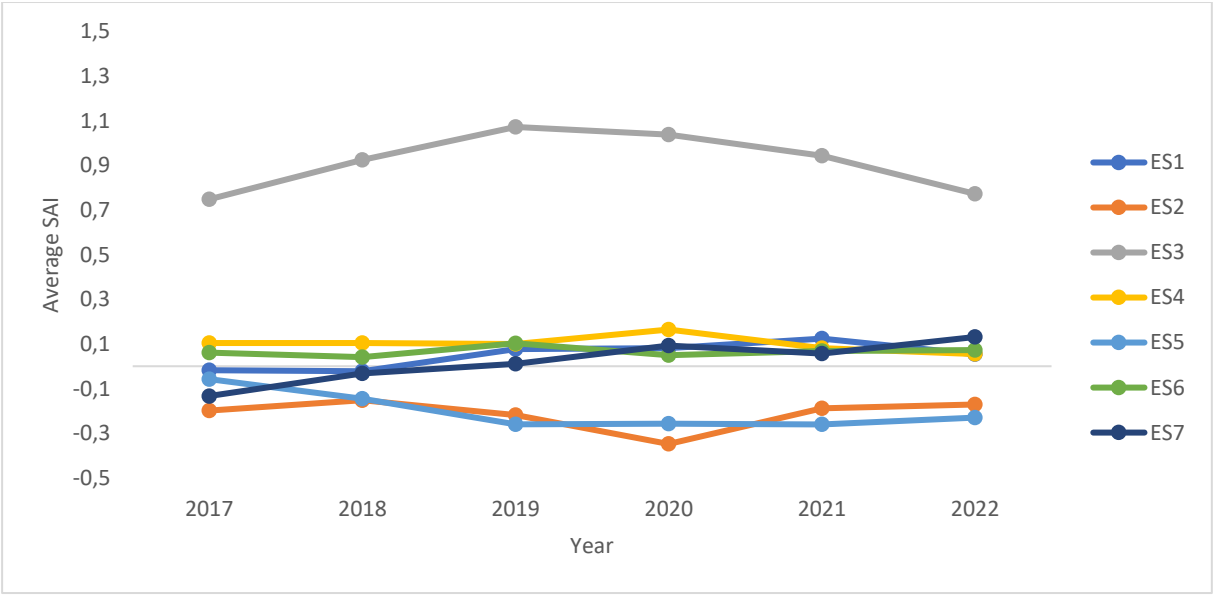


Figure 4.10 – Average SAI by Groups of Autonomous Communities

5. CONCLUSIONS

Many times, it can be a challenge to analyze socio-economic and demographic indicators when these do not follow a linear pattern with the population size of a city, region or even a country. In this study, we tried to understand the efficiency of public procurement activities on the 59 provinces of Spain. For that, it was used the USL methodology to see the efficiency of each province in the total awarded value overall and by type of contract.

It was observed that public procurement activity is increasing not just in the number of contracts awarded by also its total awarded value. With that, throughout the years, this public procurement activity tended to scale sub-linearly with the population size, which means with a bigger population size, the value *per capita* tends to be lower. This behavior happens not just overall but also by each major type of contract.

It is worth noting that the value awarded overall tends to scale linearly with the population size, since in 2022 registered a scaling coefficient of ≈ 0,86. The scaling coefficients of the three types of contracts have also registered an increasing pattern since 2018, with more significance in the Services and Works contracts.

Despite scaling coefficients give an overall perspective on the scaling behavior of the public procurement activity, there is a more efficient way to look at each province individually by using the SAI where it showed how each province deviates its real total awarded value compared to the expected value for its corresponding population size. It can also highlight some of the main differences in aspects of each major group of regions in Spain, where some of these clusters present a very positive SAI while other groups a negative SAI.

Comparing these results with similar study in Portugal by Curado *et al.* (2021), and despite his timespan work was focused from 2011-2018, Spain also registers a sublinear behavior, not just in the general aspect but also in the three main types of contracts, with very similar scaling coefficients in 2018 (Spain ≈ 0,81 and Portugal ≈ 0,78). When it comes to compare the SAI values, it is difficult to make a linear comparison as in Spain the regions compared have their own unique characteristics while in Portugal it was compared North vs South and Interior vs Coastal regions. Nonetheless it is also possible to identify a common excessive positive SAI in the capitals of both countries and some of the most populated cities/regions with an efficient spending.

Due to the fact this study was only based on a singular database available in Spain, one major limitation was not having an effective centralized portal with all procedures stored like it is in Portugal. Despite the different existing portals, some of the information is communicated to the PLACSP portal but not all the information necessary to be included in the database. One step to overcome this limitation is to have improvements on the dataset provided by PLASCP, with more contracts being available also on this portal.

Like in the study from Curado *et al.* (2021), this study also provides valuable insights on public procurement activity, what can give policymakers a wider perspective on the behaviors and patterns on public procurement activity, which can help them substantiate their decisions based on the information collected and the results obtained in this study, not just at a regional level but also at a national level.

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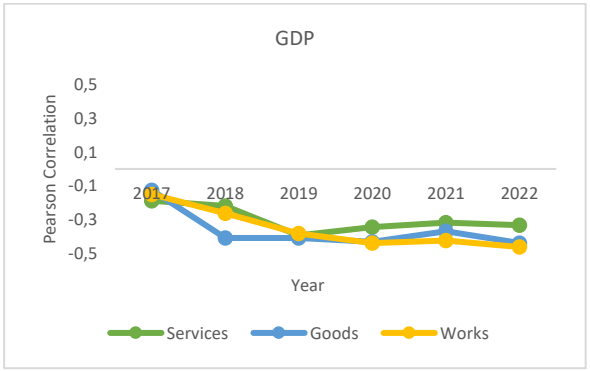
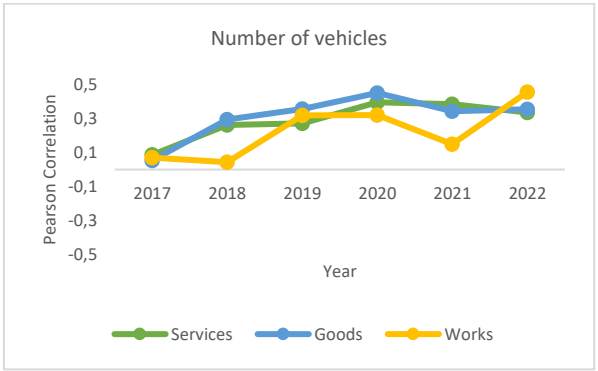
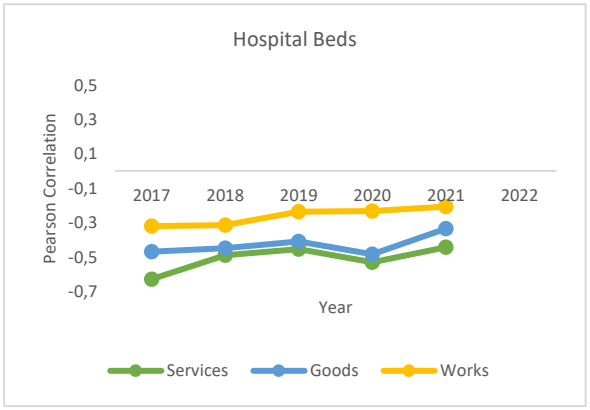
APPENDIX A (CPV TABLE WITH DESCRIPTION AND STATISTICS)

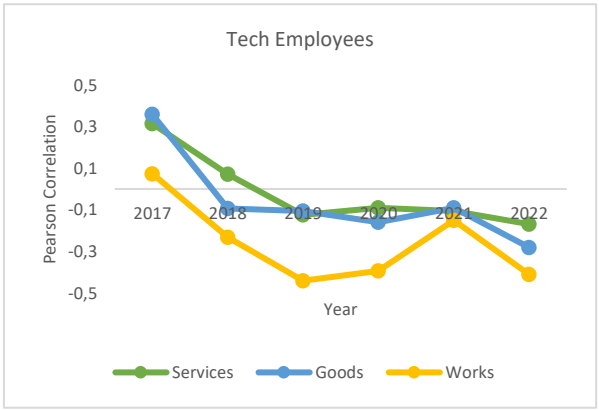
CPV	DESCRIPTION	NUMBER OF CONTRACTS	TOTAL AWARD VALUE
03	Agricultural, farming, fishing, forestry and related products	2427	232 930 364,98 €
09	Petroleum products, fuel, electricity and other sources of energy	8202	7 379 012 199,76 €
14	Mining, basic metals and related products	1433	392 487 387,65 €
15	Food, beverages, tobacco and related products	3868	1 058 337 795,35 €
16	Agricultural machinery	746	59 960 759,21 €
18	Clothing, footwear, luggage articles and accessories	4632	937 581 313,15 €
19	Leather and textile fabrics, plastic and rubber materials	355	44 046 476,88 €
22	Printed matter and related products	2852	381 189 496,60 €
24	Chemical products	2481	394 106 221,21 €
30	Office and computing machinery, equipment and supplies except furniture and software packages	13478	2 210 933 932,76 €
31	Electrical machinery, apparatus, equipment and consumables; Lighting	5679	1 343 229 039,95 €
32	Radio, television, communication, telecommunication and related equipment	4531	1 370 659 393,68 €
33	Medical equipments, pharmaceuticals and personal care products	20251	15 796 807 385,43 €
34	Transport equipment and auxiliary products to transportation	13743	13 669 602 954,55 €
35	Security, fire-fighting, police and defence equipment	4740	7 771 785 063,49 €
37	Musical instruments, sport goods, games, toys, handicraft, art materials and accessories	2232	224 365 305,34 €
38	Laboratory, optical and precision equipments (excl. glasses)	5444	1 049 468 764,77 €
39	Furniture (incl. office furniture), furnishings, domestic appliances (excl. lighting) and cleaning products	8183	979 850 220,29 €
41	Collected and purified water	103	11 945 136,57 €
42	Industrial machinery	5555	955 190 561,19 €
43	Machinery for mining, quarrying, construction equipment	972	176 932 887,87 €
44	Construction structures and materials; auxiliary products to construction (excepts electric apparatus)	10106	1 455 699 641,91 €
45	Construction work	76454	45 522 229 910,14 €
48	Software package and information systems	9330	2 239 273 226,86 €
50	Repair and maintenance services	26557	10 071 989 820,47 €
51	Installation services (except software)	1433	282 983 612,49 €
55	Hotel, restaurant and retail trade services	7734	2 139 287 077,29 €
60	Transport services (excl. Waste transport)	8407	9 071 763 872,93 €
63	Supporting and auxiliary transport services; travel agencies services	2876	2 465 258 860,52 €
64	Postal and telecommunications services	3343	2 565 449 439,42 €
65	Public utilities	575	931 850 984,48 €
66	Financial and insurance services	6793	2 031 486 175,20 €
70	Real estate services	2805	1 084 164 998,42 €
71	Architectural, construction, engineering and inspection services	21397	4 479 103 329,70 €
72	IT services: consulting, software development, Internet and support	18401	7 190 381 511,12 €
73	Research and development services and related consultancy services	1304	489 239 783,29 €
75	Administration, defence and social security services	1187	640 356 509,82 €
76	Services related to the oil and gas industry	38	3 973 515,10 €
77	Agricultural, forestry, horticultural, aquacultural and apicultural services	3621	2 087 578 049,85 €
79	Business services: law, marketing, consulting, recruitment, printing and security	26390	6 897 324 677,59 €
80	Education and training services	6575	1 320 568 569,93 €
85	Health and social work services	15882	16 644 369 540,57 €
90	Sewage-, refuse-, cleaning-, and environmental services	15045	13 782 371 487,06 €
92	Recreational, cultural and sporting services	15984	1 634 166 867,91 €
98	Other community, social and personal services	4248	1 212 640 392,94 €

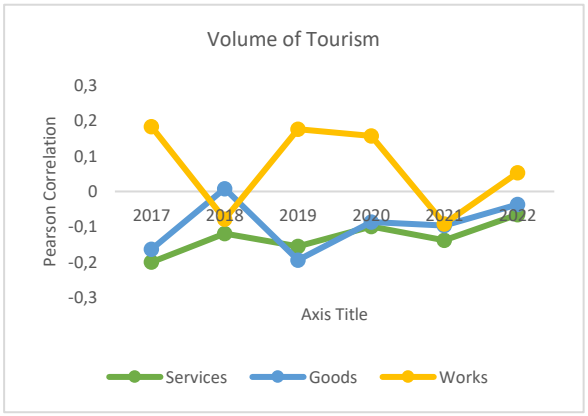
APPENDIX B (PEARSON CORRELATION BETWEEN SAI FROM PROCUREMENT AND SOCIO-ECONOMIC INDICATORS)

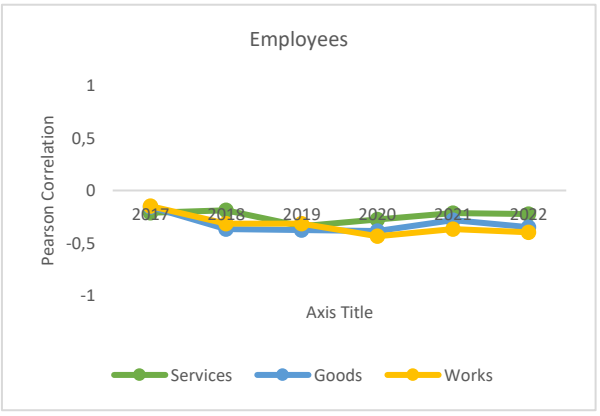


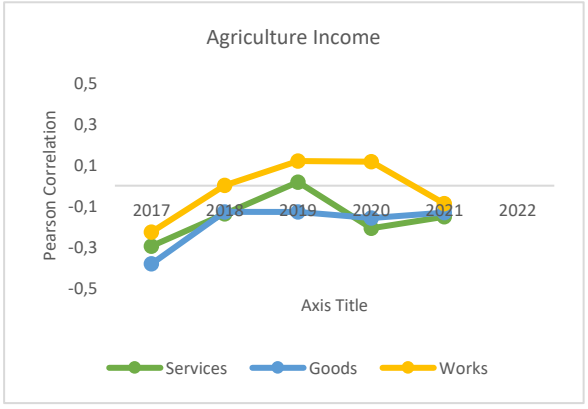


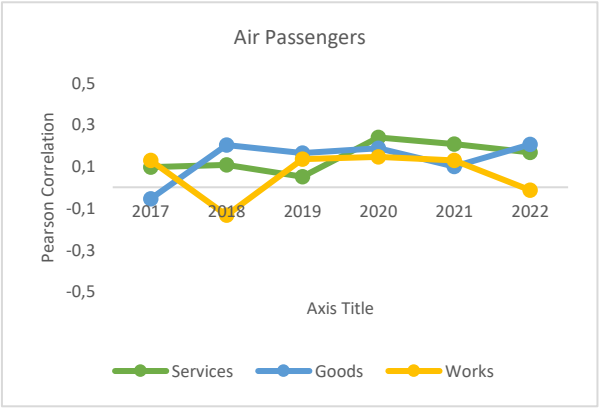


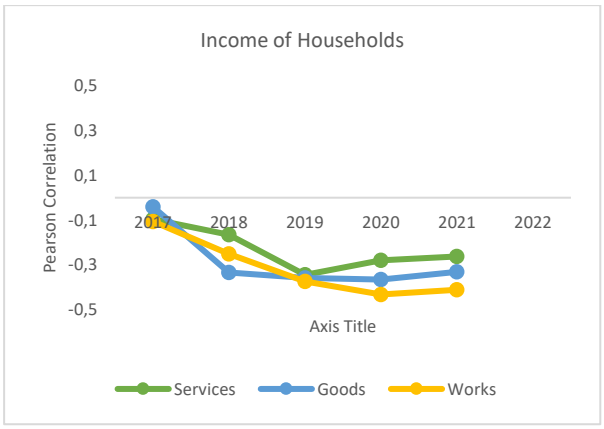


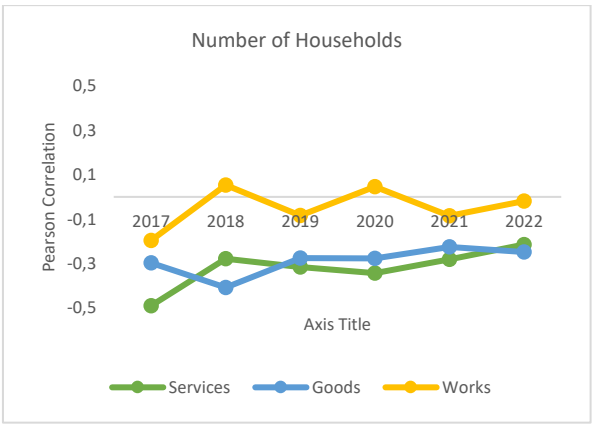


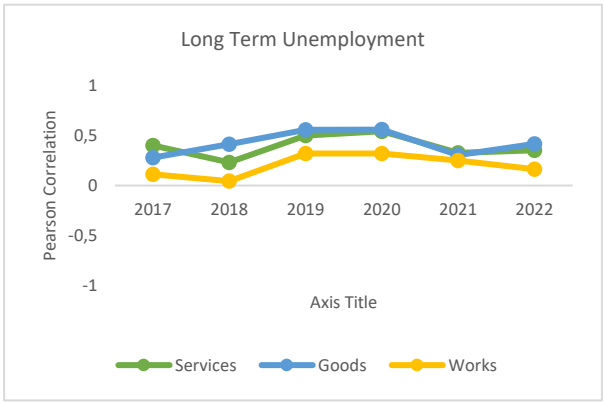




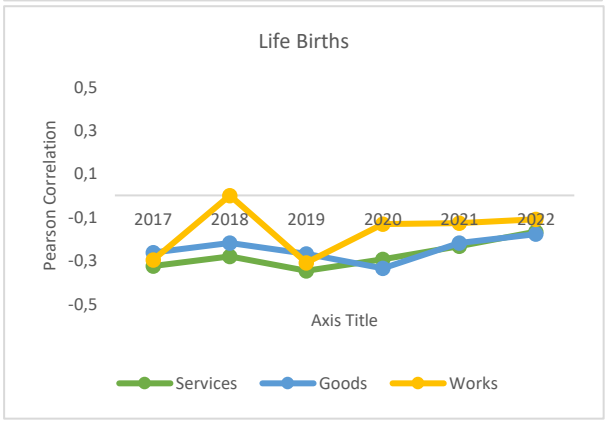


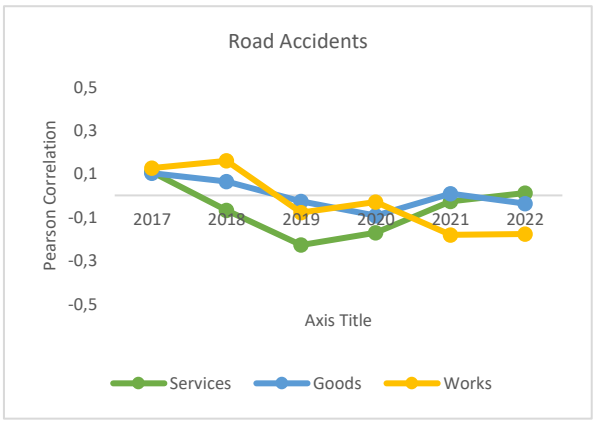

Income of Households
Pearson Correlation
0,5
0,3
0,1
-0,1
-0,3
-0,5
2017
2018
2019
2020
2021
2022
Axis Title
Services
Goods
Works


Number of Households
Pearson Correlation
0,5
0,3
0,1
-0,1
-0,3
-0,5
2017
2018
2019
2020
2021
2022
Axis Title
Services
Goods
Works


Long Term Unemployment
Pearson Correlation
1
0,5
0
-0,5
-1
2017
2018
2019
2020
2021
2022
Axis Title
Services
Goods
Works


Total Transported Goods
Pearson Correlation
1
0,5
0
-0,5
-1
2017
2018
2019
2020
2021
2022
Axis Title
Services
Goods
Works


Life Births
Pearson Correlation
0,5
0,3
0,1
-0,1
-0,3
-0,5
2017
2018
2019
2020
2021
2022
Axis Title
Services
Goods
Works


Road Accidents
Pearson Correlation
0,5
0,3
0,1
-0,1
-0,3
-0,5
2017
2018
2019
2020
2021
2022
Axis Title
Services
Goods
Works