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EVALUATING GREEN PUBLIC PROCUREMENT IN PORTUGAL: AN ANALYTICAL APPROACH

Catarina da Cruz Janeiro

A dissertation submitted in partial fulfilment of the requirements
for the degree of Master's in Statistics and Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade NOVA de Lisboa

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by

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Dissertation presented as partial requirement for obtaining the Master's degree in Statistics and Information Management, with a specialization in specialization in Data Analytics

Supervised by:

Bruno Miguel Pinto Damásio, PhD, NOVA Information Management School
Flávio Luís Portas Pinheiro, PhD, NOVA Information Management School

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Abstract

This thesis aims to investigate the diffusion of Green Public Procurement in the Portuguese context using network science and panel data regression. Using data from Portal BASE platform from 2018 to 2023, a proximity network of services based on Revealed Comparative Advantage (RCA) is constructed. The study tests, for each company that has celebrated public contracts, whether services that are structurally close to already green services are more likely to adopt green practices over time. Afterwards, the objective is to analyze whether services structurally close to already green services exhibit higher green adoption rates in the future. Contrary to expectations, the results reveal a negative association between proximity to green services and future green adoption. Specifically, services located near green ones in the network are less likely to become green themselves unless they are associated with higher contract volumes, in which case a moderately positive effect emerges. This study contributes to the understanding of how service interdependencies influence the adoption of sustainable practices. It may also provide insights relevant to policies in terms of accelarating the green transition.

Keywords: Public Procurement, Product Space, Ordinary Least Squares (OLS), Green Products

Sustainable Development Goals (SDG):

Resumo

Esta tese tem como objetivo investigar a difusão da Contratação Pública Verde no contexto Português utilizando análises de rede e regressão com dados em painel. É construída uma rede de proximidade baseada na Vantagem Comparativa Revelada (RCA) utilizando os dados da plataforma Portal BASE referentes aos anos de 2018 a 2023. O estudo analisa, para cada empresa que celebrou contratos públicos, se os serviços estruturalmente próximos de serviços já considerados verdes têm maior probabilidade de adotar práticas sustentáveis ao longo do tempo. Posteriormente, o objetivo é analisar se os serviços estruturalmente próximos a serviços verdes exibem taxas de adoção verde mais altas no futuro. Contrariamente às expectativas, os resultados revelam uma associação negativa entre a proximidade a serviços verdes e a adoção futura de critérios ambientais. Especificamente, os serviços localizados próximos de outros já verdes na rede têm menor probabilidade de se tornarem verdes, a menos que estejam associados a volumes contratuais mais elevados, cenário no qual se observa um efeito moderadamente positivo. Este tese apresenta contributos para melhorar o entendimento sobre como a interdependência entre serviços influencia a adoção de práticas sustentáveis. Adicionalmente, também destaca possibilidades de melhoria de regulamentações de políticas públicas relativamente à aceleração do processo de transição verde.

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List of Acronyms and Abbreviations

CPV Common Procurement Vocabulary *(p. 21)*

EU European Union *(pp. 1, 3–5)*

GPP Green Public Procurement *(pp. 1, 3–5, 9, 10, 20)*

MST Maximum Spanning Tree *(p. 21)*

OECD Organization for Economic Co-operation and Development *(p. 3)*

OLS Ordinary Least Squares *(pp. 6, 8, 10, 20, 23)*

PP Public Procurement *(p. 3)*

RCA Revealed Comparative Advantage *(pp. 1, 6–8, 18)*

SDG Sustainable Development Goals *(p. 5)*

1

Introduction

Public procurement represents a significant share of national expenditure and has increasingly become a strategic lever for achieving sustainability goals, especially within the European Union (EU) (European Commission, 2023). Green Public Procurement (GPP) can be a policy tool in which the process used by public entities to procure goods and services, while emphasizing the reduction of environmental impacts through the entire life cycle of said goods or services can enable governments to influence production and consumption patterns. (Bargues et al., 2019)

Portugal, aligned with EU directives and guided by national strategies such as the ECO360 – ENCPE 2030 (Diário da República, 2023), has made strides in promoting GPP. In the EU, the Circular Economy Package and the EU Green Deal integrate GPP policies into broader environmental frameworks. (Pouikli, 2020; Tátrai & Diófási-Kovács, 2021) However, the effectiveness and diffusion of green practices across public services remain uncertain. In this context, this dissertation explores the role of service interconnectivity in fostering green procurement.

Using a product space approach adapted from international trade and complexity economics, one can build proximity networks of services using Revealed Comparative Advantage (RCA) and co-occurrence matrices (Hidalgo et al., 2007). The objective is to combine the product space analysis of Ribeiro (2021) on the Portuguese public procurement data and of Fraccascia et al. (2018) on the perspective of green growth through proximity to green products. Additionally, a panel data OLS regression is applied to the product space data to assess if, for each company's produced services, being close to already green services increases green adoption in subsequent years.

The results of this study suggest a surprising negative relationship between proximity to green services and subsequent green growth, which becomes positive when paired with higher contract volumes. These results may be explained by a lack of

knowledge from contracting authorities' technicians, misapplication of regulation (Bargues et al., 2019), or having the innovation adoption cost overcoming potential gains (Ghisetti & Rennings, 2014). The thesis gives a path for further exploration of how public procurement influences private decisions, with possible applications being the region or sector analysis, or a deep dive into contracts' content. The following sections further explore these dynamics, presenting the methodology, data analysis, and key findings that offer insight into how green practices evolve within public procurement networks in Portugal.

2

Literature Review

2.1 Public Procurement

Governments procure private companies' services for national or regional activities, such as maintaining public infrastructures (Curado et al., 2021). The European Union (EU) governments operate under similar social, economic and often political spaces with unpredictable and complex environments. Public Procurement (PP) accounts for 14% of GDP (about €2 trillion per year) across several sectors from transportation to social protection, education, healthcare, and many others (European Comission, 2019).

PP is increasingly seen by the EU as a strategical instrument (European Commission, 2023). The Organization for Economic Co-operation and Development (OECD) has promoted transparency on the public procurement cycle (OECD, 2015). Previous studies reveal the need for more research on public procurement, and all its variants as a way to open up the box of public management, transparency and civil society supervision (Fazekas & Blum, 2021).

2.2 Green Public Procurement

The interaction between sustainability impacts and Green Public Procurement (GPP) is a complex area of study that encompasses various institutional alterations and external forces. Multiple studies show the need for robust legal frameworks promoting sustainability through public procurement. This highlights the role of regulation in the implementation of environmentally-friendly strategies.

With GPP, public authorities are able to influence market behaviors and promote sustainability production and consumption practices. GPP refers to the practice of purchasing goods, services, and works with reduced environmental impacts (European Commission, n.d.). Furthermore, Bargues et al. (2019) define GPP as the process by

which public entities procure goods and services emphasizing the reduction of environmental impacts through the entire life cycle of said goods or services. This strategy is increasingly recognized as fundamental for attaining sustainability objectives.

Within the EU, GPP policies are integrated into broader environmental frameworks such as the Circular Economy Package and EU Green Deal (Pouikli, 2020; Tátrai & Diófási-Kovács, 2021). In terms of regulations, GPP is subject to European Union Procurement Directives, Directive 2014/24/EU (European Commission, 2014a) and Directive 2014/25/EU (European Commission, 2014b). These frameworks incentivize public sector actors to adopt ecological criteria in their practices, and therefore, hopefully, help create incentives for suppliers to adopt green practices as well.

Halonen (2021) mentions the variability in environmental impacts across sectors, highlighting that sector-specific regulations may be essential for GPP success. The understanding of this variability suggests that there are sector-specific challenges and capabilities in the adoption of sustainable practices.

Simcoe and Toffel (2014) observed that effective regulation, and institutional reforms stimulate the adherence of the public sector to GPP guidelines, but may also create spillover effects into the private sector. This analysis points out that public procurement policies can influence the behavior of the private sector, with a greater adoption of sustainable practices in diverse areas, which demonstrates the potential of regulation in the extension of their influence beyond public procurement. When effective, public procurement can ease the shift towards greener and more sustainable practices in the overall economy.

Nonetheless, GPP implementation is usually challenged by institutional inertia and the complexity of integrating sustainability into already existing procurement processes. Public institutions often have to overcome several barriers, such as inconsistencies in regulatory definitions regarding sustainability, as well as lack of knowledge (Vluggen et al., 2019). The successful implementation of sustainable practices stems from a set of factors such as motivation, opportunity and ability. This suggests that, for a successful implementation, not only the foundation provided by regulations is needed, but there may also be the need for additional support and training in order to give the required capabilities to public procurement entities and procurers (Grandia & Voncken, 2019).

2.2.1 Impact of Green Public Procurement in European Countries

GPP has gained traction across Europe as a strategic approach in the integration of sustainability in public practices. Findings indicate several degrees of implementation

and success among member states. Countries like Denmark and the Netherlands have effectively used electronic public procurement platforms to improve competition and transparency, promoting an environment with greater engagement from green suppliers and enhancing environmentally sustainable practices, while Portugal has seen a deterioration of public procurement practices after the implementation of e-procurement (Mélon & Spruk, 2020). Bargues et al. (2019) studied the use of environmental criteria in the public tenders of the Valencian public administration. This study concludes that there is the need to improve GPP practices in the Valencian administration, specifically in local scopes.

Research suggests that the degree of adoption of GPP is not yet consistent, and needs targeted interventions to attain uniformity across the EU (Pouikli, 2020; Tátrai & Diófási-Kovács, 2021). The results highlight the importance of specified strategies for each country's context and capabilities so that public procurement initiatives across Europe achieve optimized environmental benefits.

2.3 The Portuguese Context

For the Portuguese Context, the adaptation of the European Directives has stemmed from an alteration of the Public Procurement Law (Código dos Contratos Públicos – CCP), through the Law-Decree nº 111/2017. (Diário da República, 2017) This alteration introduced the definition of Life Cycle Costing – accounting for all costs throughout the lifecycle of a product, including environmental externalities (European Commission, 2024).

The newest of the strategies, ECO360 – ENCPE 2030, adopted in 2023 through the Ministers' Council Resolution (Diário da República, 2023) defines the vision and objectives of the public purchases in Portugal, and is considered a strategical tool to achieve the Sustainable Development Goals (SDG) goals in the portuguese economy (ENCPE, 2020).

From 2007 onwards, there have been three sequential national strategies with the objective of ensuring and monitoring the implementation of GPP:

1. The National Strategy for the Ecological Public Purchases (ENCPE);

2. The National Strategy for the Ecological Public Purchases 2020 (ENCPE 2020) (ENCPE 2020);

3. The ECO360 - the National Strategy for the Ecological Public Purchases 2030 (ECO360 - ENCPE 2030)

2.4 Methodology

This work will explore Public Procurement data with the objective of characterizing the evolution of green contracts across time. The first part of the analysis will be done by leveraging on the product space method to characterize the network of services contracted to private entities. The second part will consist of an Ordinary Least Squares (OLS) regression, taking into account computations stemming from the product space analysis.

2.4.1 Product Space

The product space method - a tool coming from complexity economics - offers a view of economic development by analyzing the relationships between products that countries export. It maps the products based on the capabilities required to produce them. Therefore, when two activities, services or products required similar knowledge or inputs to be executed, they will be mapped closer together than if they require different capabilities. The underlying idea is that countries move through this product space by leveraging on existing know-how to produce new, more complex goods, which in turn, increases their growth potential and economic complexity (Hidalgo et al., 2007).

The Revealed Comparative Advantage (RCA) is used as an economic index that computes whether a country has an advantage or a disadvantage on the trade flows of a certain commodity. A country may choose to export the products it has produced and in which it detains a comparative advantage. As an example, for the production of avocados, Mexico detains a comparative advantage over other countries.

The RCA formula will relate companies with the offered services (i.e. the services sold by companies, based on the Portuguese total market share). The formula of RCA, accounting for companies, c, and services, s and s', instead of countries and products, can be defined as (Balassa, 1965; Fraccascia et al., 2018):

$$\mathrm{RCA_{cs}} = \frac{\frac{\mathrm{E_{cs}}}{\sum_s \mathrm{E_{cs}}}}{\frac{\sum_c \mathrm{E_{cs}}}{\sum_c \sum_s \mathrm{E_{cs}}}} \tag{2.1}$$

where E_{cs} ($E_{cs'}$) is the value of service s (s') produced by the contracted entity c. Having RCA_{cs} ($RCA_{cs'}$) > 1 means that the entity has a competitive advantage in service s (s').

Relatedness in the product space is the idea that the probability of a country starting exporting a product increases with the number of related products that this country already exports (Hidalgo et al., 2018). This idea can be leveraged for the purpose

of this thesis in order to try to understand whether the probability of a company's service becoming green increases with the number of green services that said company already provides, that are close to the first one.

Employing the model of Ribeiro (2021), which is based on the model detailed in Hidalgo et al. (2007), the proximity between two services, s and s' is the minimum conditional probability that a private organization has a RCA in both services. Formally, it can be expressed as:

$$\varphi_{s,s',t} = \min \{P\left(\text{RCAx}_{cs,t} > 1 | \text{RCAx}_{cs',t} > 1\right); P\left(\text{RCAx}_{cs',t} > 1 | \text{RCAx}_{cs,t} > 1\right)\} \quad (2.2)$$

where the first probability is the probability that service s is competitively produced by company c, given that service s' is competitive, and the second is the probability that service s' is competitively produced by company c, given that service s is.

This methodology will map the level of relatedness of services provided by private entities to the Portuguese public entities. Therefore, when a contracted entity has a RCA > 1 on a given service, it is considered to be an effective producer of said service. The contrary also applies.

The specialization matrix X_{cs} can be used to compute proximity by organizing service data and summarizing contract values (in euros) of a company, c in a service, s.

Furthermore, to compute the conditional probabilities Fraccascia et al. (2018) uses the following formula:

$$P(RCA_s > 1 | RCA_{s'} > 1) = \frac{\sum_c \text{M}_{\text{cs}} \text{M}_{\text{cs}'}}{\sum_c \text{M}_{\text{cs}}} \quad (2.3)$$

where *Mcs* (*Mcs'*) is equal to one if RCAcs > 1 (RCAcs' > 1), otherwise it is equal to zero. RCAcs (RCAcs') is the Revealed Comparative Advantage of product i (j) for service s.

Particularly in the green product context, when a green product is close to a product with RCA > 1, it is more likely that the country has the capability to produce that green product successfully [1]. Therefore, there is a higher probability that the country will successfully include the green product within its product space, making them better candidates for growth than those with lower proximity (Fraccascia et al., 2018). Hamwey et al. (2013) proposes a similar idea by developing the "green product space

[1] The words product and service are use interchangeably throughout this thesis.

methodology", in which the higher the proximity of a green product to a product with RCA > 1, the better that green product is considered a prospective competitive product.

Huberty and Zachmann (2011) use the product space to test whether industrial policy purposefully supporting green growth can improve the competitiveness of green products. To test this, Huberty and Zachmann (2011) analyze the growth in RCA of two green products - solar panels and wind turbines -, and find that the only variable, out of the investigated ones, affecting positively the growth of both products is the proximity to products that are a source of competitive advantage. Hamwey et al. (2013) employs the product space to Brazil's market to examine which green products are likely to have a comparative advantage by their proximity to products that already have one. Fraccascia et al. (2018) performs regression analysis to test if the green products with highest proximity to the products with high RCA have the most potential for growth. In this study, 141 countries are included between the years of 2005 and 2013. Lastly, Ribeiro (2021) uses the product space to map a public procurement proximity network. This thesis aimed to analyse the services offered by private entities and contracted by Portuguese public entities, in an effort to understand how the public procurement space is structured.

2.4.2 Ordinary Least Squares Regression

The OLS method is a commonly used tool for studying the relationship between different variables. In this research, OLS is used to explore how green contracts have changed over time. By including product space parameters, the factors that influence the adoption of environmentally friendly practices can be better understood.

The OLS regression model is specified as:

$$y_i = \beta_0 + \beta_1 \log(x_{i1}) + \beta_2 x_{i2} + \varepsilon_i \tag{2.4}$$

Where y_i is the dependent variable, x_{ni} are the explanatory variables and ε_i

2.5 Product Space on Green Public Procurement (GPP)

The product space methodology can be adapted to analyze public procurement data in Portugal, in order to offer insights into potential green product development. The application of this methodology to the Portuguese public procurement context requires an exploration of how regulatory frameworks and procurement practices align with sustainability objectives.

As previously mentioned, the Portuguese government has included GPP into its procurement processes. Its objective is to foster a market for sustainable goods and services, and at the same time, minimize the environmental impacts. This is particularly relevant in circular procurement, which emphasizes life-cycle costing and sustainable practices in all phases of product procurement (Tátrai & Diófási-Kovács, 2021). One example is to implement GPP criteria into tenders, which may generate demand for innovative sustainable products. (Alhola et al., 2018).

Regulatory pressure can impact the future of public procurement practices (Ciumara & Lupu, 2020). Moreover, increasing regulation in Portugal could encourage advancements in sustainability by motivating local entities to prioritize environmentally friendly products. Analysing public procurement data can reveal how often green criteria is used, which sectors are the most affect, and what are the outcomes of these practices on supplier engagement and market development of green products.

Public procurement goals should be aligned with broader European objectives. The EU has put emphasis on GPP strategy, which provides Portugal with a structured framework for innovative practices that meet immediate needs but also ensure long-term sustainable practices (Giné et al., 2022). Testa et al. (2016) add that public procurement may help achieve sustainability goals and influence production and consumption trends. By leveraging on the governments purchasing power, it is possible to promote environmental shifts in the industry.

Analysing the data regarding the effectiveness of green public procurement in Portugal may aid in the clarification of barriers or enablers to improve the implementation of GPP. A data-driven approach can provide insights on successes and challenges related to the sustainability of public tenders, and facilitate strategic adjustments to enhance green product development (Halonen, 2021)

The product space was developed to characterize international trade. However, leveraging on the application of the product space on public procurement data in Portugal by Ribeiro (2021), and by focusing this analysis in the possible effect that greener services have on non-green (or less green) services overtime, several limitations arise. Most of these limitations originate from the comparative analysis of national data rather than that of a broad international perspective. While the application of a country product space analysis to Portuguese public procurement data may present valuable insights into green service development, the limitations inherent in a national scope must be carefully considered.

The article by Fraccascia et al. (2018) explores the application of the product space

framework as policy-making tool for green product development. Furthermore, the authors apply OLS regression analysis to conclude on the statistical significance of some factors influencing green product development.

The implications of this research offer insights in framing policies to promote GPP. Although not applied to international trade, by understanding the interconnectedness of products in the product space, policymakers in Portugal can better select which green products to foster in public procurement initiatives to expedite their transition towards sustainability.

3

Materials and Methods

This chapter will describe the datasets used, and detail the process of cleaning the data. Additionally, it will also present the data exploration done on both datasets to further understand them. Figure synthesizes the process from data retrieval to results.

3.1 Data Preparation

3.1.1 Data Cleaning

The data used for the analysis comes from Portal BASE database, which is the official Portuguese Database for Public Procurement, and comprises the public contracts ranging from 2009 to 2023. The analysis will only be applied from 2018 onwards, considering the change in the Public Procurement Law in 2017. The dataset includes all contracts celebrated with public entities throughout this timeframe. In Table 3.1, is a characterization of the columns used in the dataset.

To further characterize the dataset, there are numerical and non-numerical data. For the numerical data, Table 3.2 statistically describes it to understand how the data is distributed.

Before conducting further analysis on the dataset, it is crucial to perform data cleaning and pre-processing to ensure good quality and coherent data, as well as data completeness. As such, the next steps are:

1. Analysing missing values
2. Ensure uniqueness of contracts
3. Correcting data types and standardizing formats
4. Correcting data and filtering out irrelevant data

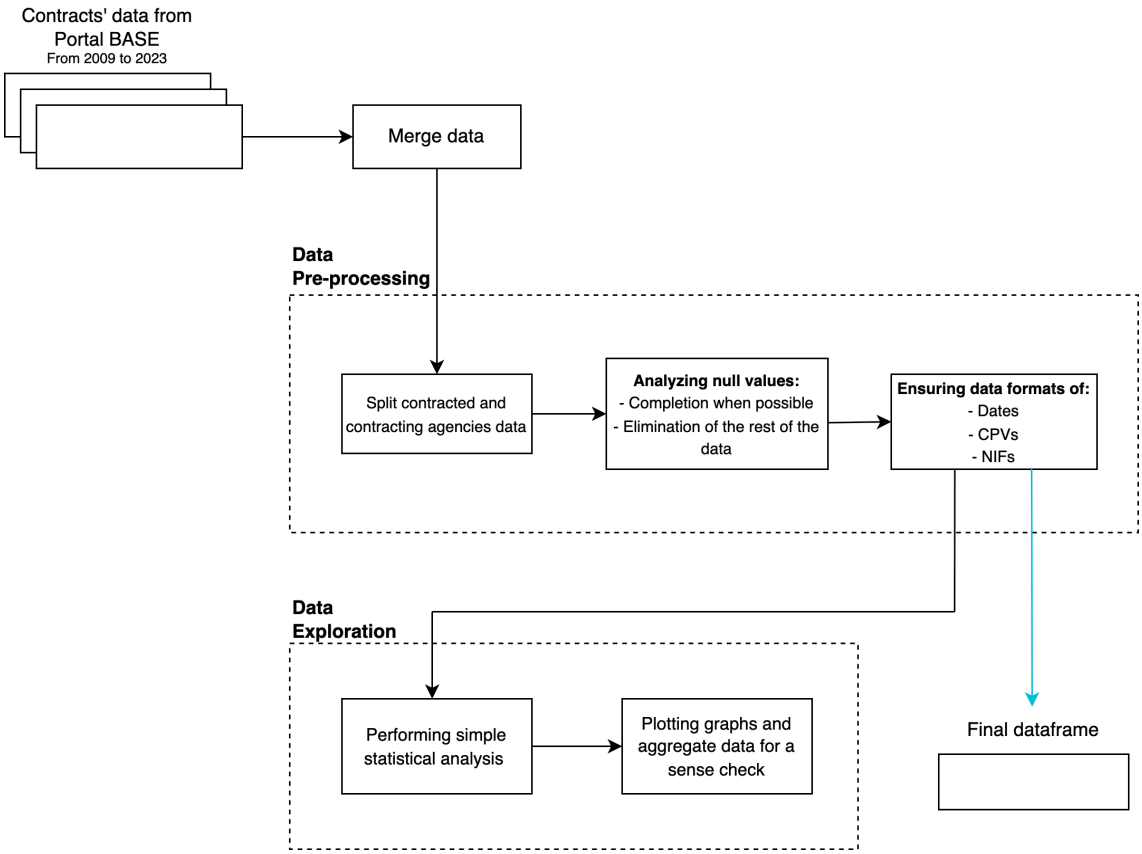


Figure 3.1: Data Process

Column name	Data Type	Column Description
id	Integer	Unique identification of the line
contract_id	Integer	Unique identification number of the contract
cpvs	String	Common Procurement Vocabulary Code
execution_deadline	Integer	Number of days until the completion of the project
initial_price	Float	Contract's initial price
final_price	Float	Contract's final price
signing_date	Date	Date of the signed contract
environmental_criteria	Boolean	Whether the procedure has environmental criteria or not
contracted_description	String	Name of the contracted company
contracted_nif	String	Fiscal number of the contracted company
contracting_agency_description	String	Name of the entity that is adjudicating the contract
contracting_agency_nif	String	Fiscal number of the entity that is adjudicating the contract

Table 3.1: Columns Description

Statistic	execution_deadline	initial_price	final_price
count	1 726 808	1 726 808	586 309
mean	1 280	62 922	58 517
std	453 618	1 114 972	2 625 862
min	0	-10 566 000	0
25%	21	3 370	2 935
50%	90	10 514	9 420
75%	365	29 527	24 510
max	509 948 286	881 534 656	1 496 713 657

Table 3.2: Numerical Variables' Statistics

Column name	Missing Values	% of Missing Values
final_price	1 264 023	73.20 %
contracted_description	15	0.00 %
contracted_nif	15	0.00 %
contracting_agency_description	9	0.00 %
contracting_agency_nif	9	0.00 %

Table 3.3: Missing Values

Table 3.3 presents the missing values for the important columns of analysis. In the case of the contracted and contracting agencies data, the lines with missing values will be dropped. However, for the case of the final price, when empty it is possible to populate this column with the initial price.

The third step is to ensure that there are no duplicated contracts. In this dataset, there were 362 798 duplicated rows, which were eliminated.

Furthermore, by dropping the rows with either contracted or contracting agencies data empty, 143 822 more lines were eliminated. Additionally, it was decided to keep only Portuguese contracted and contracting agencies. Therefore, the next step in the data cleaning process was to ensure data format of contracting and contracted agencies NIFs - 9 digits. Following this step another 18 101 rows were dropped from the dataset stemming from foreign nifs in contracted agencies.

3.1.2 Data Exploration

Following the characterization of the dataset and the initial data cleaning, the next step is to explore the dataset. Figure 3.2 and figure 3.3 are bar plots of the count and sum of contract values throughout the years. The green criteria is a binary flag characterizing each public procurement contract as having, or not, environmental criteria associated to it. It is noticeable that the green criteria only starts in 2018, which is in line with the CCP review of 2017. Additionally, the amount of contracts as well as the sum of its values seems to be increasing over time. One can also see that the proportion of green

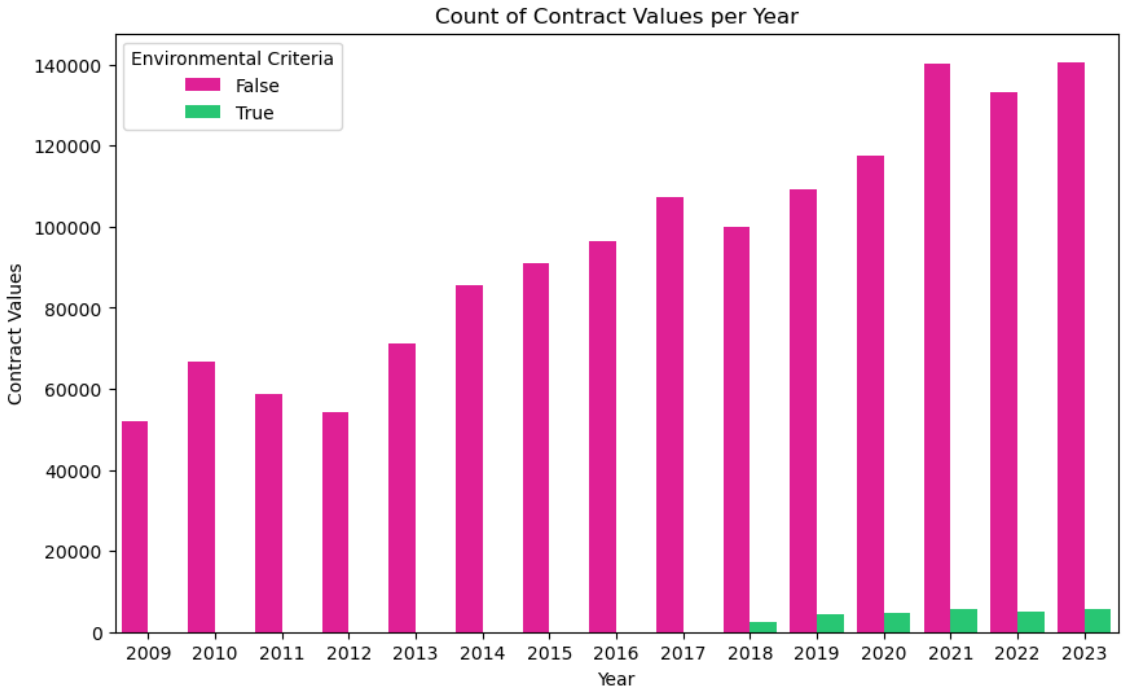


Figure 3.2: Count of Contract Values per Year

flagged contracts is much smaller than the contracts without green criteria.

Besides these plots, it is also important to analyze the behavior of the distribution of the public procurement data. Figure 3.4 and figure 3.5 are the plots of the density curves of all contract values and green contract values, respectively. Both plots present a somewhat normal distribution of contract values, though the plot with all the contract values appears to be skewed to the left more than the green contract values plot.

After performing an initial analysis and cleaning of the dataset, the next step is to prepare the dataset for the network analysis. Therefore, this chapter will detail:

- CPV Level Selection: choosing at which level of CPV precision the network analysis will be done by balancing data accuracy and green criteria
- Dataset Preparation: finalizing the dataset with which the analysis will be performed by dropping columns, grouping elements, and other data manipulation.

3.2 CPV Level Selection

The CPV is a coding system established by the EU to standardize the references used when describing the subject of procurement contracts, which helps both contracting

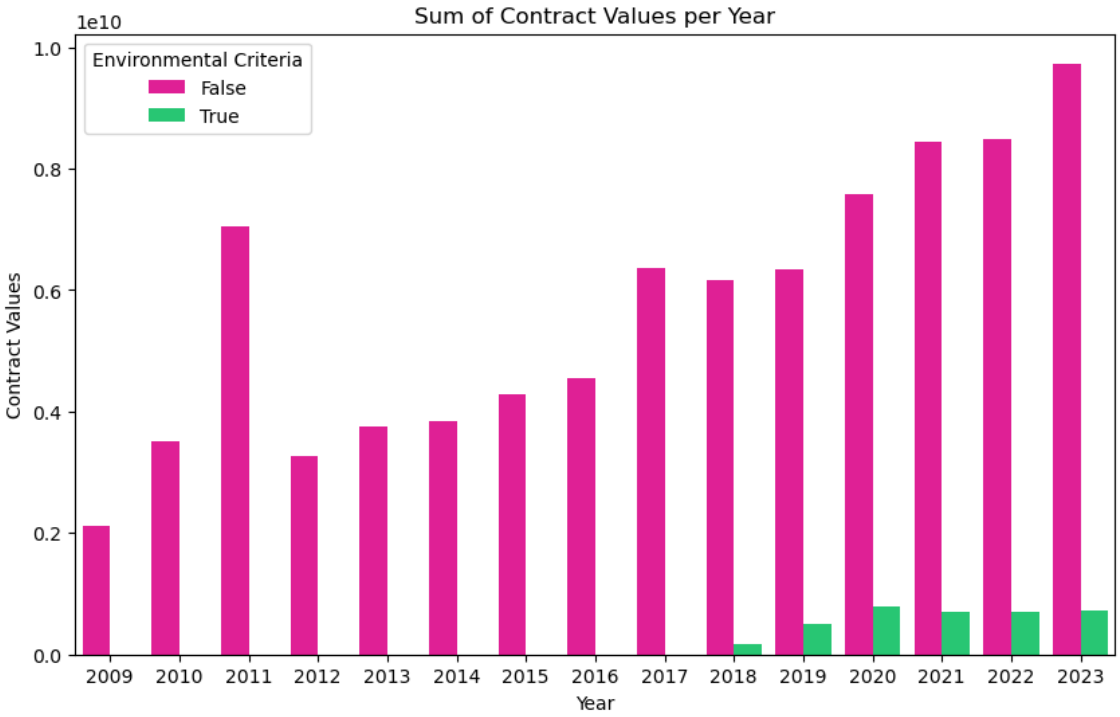


Figure 3.3: Sum of Contract Values per Year

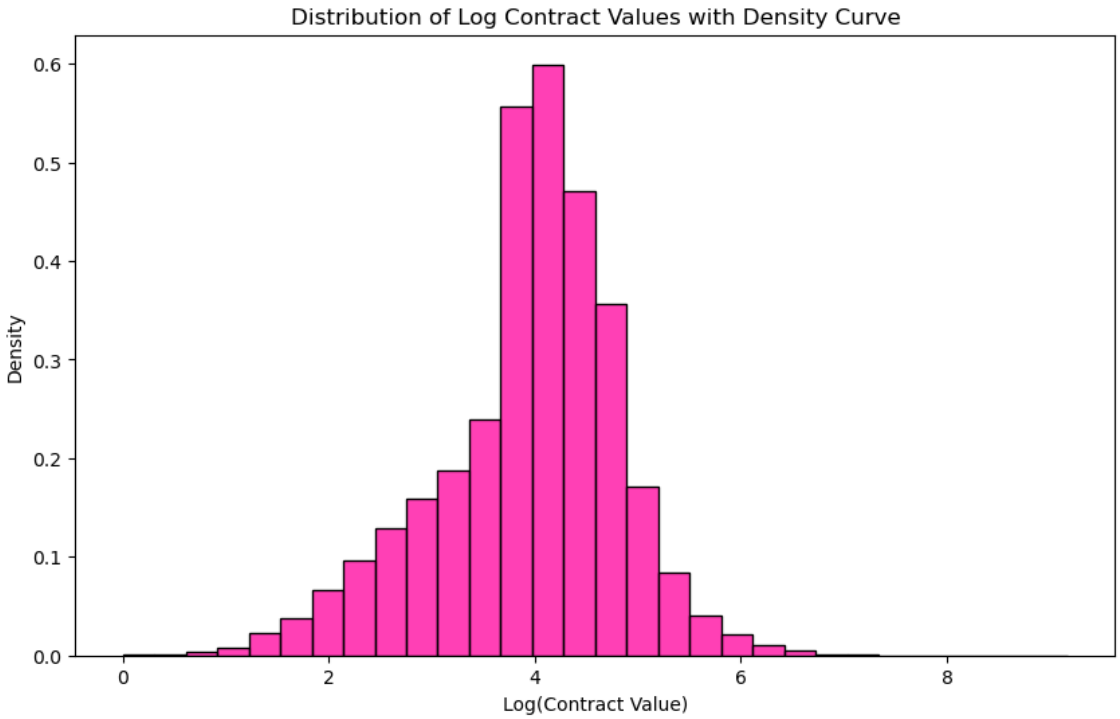


Figure 3.4: Density Curve of Contract Values

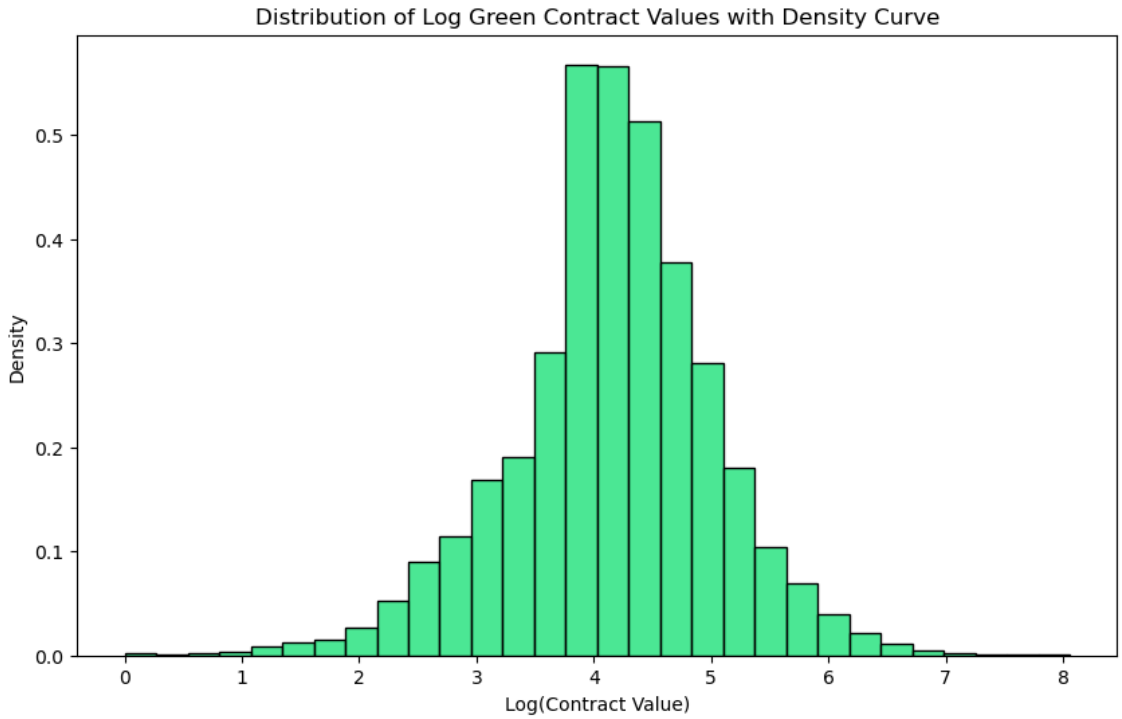


Figure 3.5: Density Curve of Green Contract Values

authorities and contracted entities. This coding system enables higher transparency, comparability and efficiency in Public Procurement.

Moreover, the CPV has several levels of coding granularity, as described in an example in Table 3.4. The levels of precision in the CPV codes are structured hierarchically, with 9 digits for each code, in which the 9th digit (Y) has a validation purpose (Publications Office of the European Union, 2025):

- **Divisions:** First 2 digits (**XX**000000-Y)
- **Groups:** First 3 digits (**XXX**00000-Y)
- **Classes:** First 4 digits (**XXXX**0000-Y)
- **Categories:** First 5 digits (**XXXXX**000-Y)
- The other three digits specify with greater precision within each category.

This structure allows for multiple levels of description, from broad sectors to highly specific products or services. Depending on the research goals, the level of CPV precision selected in a study can significantly shape the analytical outcomes, because different levels of aggregation influence the interpretability, robustness, and focus of results.

Precision Level	Code	Description
Division	**45**000000-7	Construction work
Group	45**1**00000-8	Site Preparation work
Class	451**1**0000-1	Building demolition and wrecking work and earthmoving work
Category	4511**1**100-9	Demolition work
Sub-category	45111**291**-4	Site-development work

Table 3.4: CPV Codes Precision Levels

Using high-level CPV codes (e.g., divisions or groups) is advantageous for macro-level analyses. This approach was adopted in studies such as Ribeiro (2021), who selected Level 2 CPV codes to construct a service proximity network that balances semantic resolution and data coverage. Ribeiro (2021) chose level 2 (3 digits of the CPV) after searching for a balance between data loss due to inaccuracy or incorrectedness, and contract differentiation.

The approach in this work will be to balance the precision level with the green criteria flag and the data inaccuracy/incorrectedness. As a first assessment, the CPV codes were tested against a master table. Only 200 lines appeared to have bad codes, but taking a closer look, most of these were because the inputted codes were the old ones. Since the master table had a one-to-one correspondence between the old and current codes, these lines were corrected. The other ones were, in fact, incorrectly inputted codes, leaving 113 rows to be eliminated.

The next step on the analysis is to test at which level of precision it is possible to see green criteria having a representative weight for each CPV. For that, the mean of the green flag was computed for each code at each of the possible levels. At the first level, the highest average of green criteria doesn't reach 7%. Moving to level 2, and this value increases to 19%. At level 3, we see the first code with 100% of the contracts being identified as green. Lastly, at level 4 there is more than one code with 100% of green contracts.

Considering that too much precision will hinder the analysis as it will make the network extremely scattered and make it difficult to interpret. In level 3, there are 1249 different codes, whilst in level 4 there are 3213 different codes. Both of these levels have too many codes for interpretation purposes. As such, level, with 315 codes, may be the best tradeoff between the two.

3.3 Procurement Services Proximity Matrix

After choosing the CPV level at which the analysis will be performed, it's important to characterize the specialized matrix, X_{cs}, which permits for the individual interpretation of the share of contracted entities and their offered services.

The objective is to measure the proximity between different services, leveraging on the CPV. To compute the proximity between services, it is needed to compute the probability that a company selling service s is also likely to sell service s'. As stated in equation 2.2, the proximity is the minimum conditional probability that a company has a RCA > 1 for both services.

The service space from the square proximity matrix is created with Level 2 combinations (315x315 entries). This matrix is symmetric and sorted by CPV code. Each element of the matrix represents the pairwise proximity between two services. Figure 3.6 is a heatmap of some of the services of the proximity matrix, and it's possible to see that the proximity between services is actually quite scarce. This concludes that many services are very loosely relatable to one another.

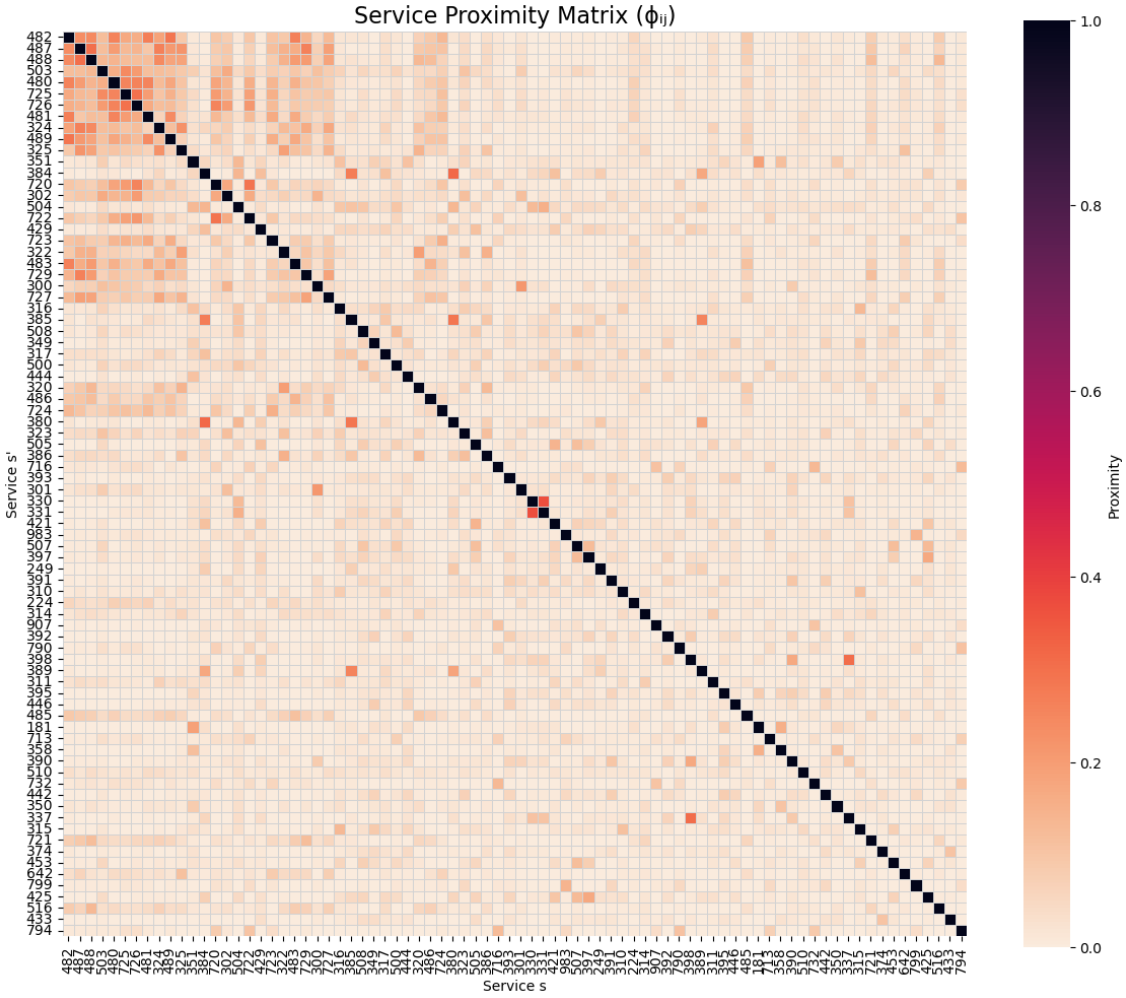


Figure 3.6: Heatmap of the Service Proximity Matrix

4

Results and Discussion

In this chapter, the results of the network analysis through time (2018-2023) will be presented, along with an OLS Panel regression analysis. The objective was to test whether the service space facilitates, or not, the diffusion of green practices through proximity. Using the theoretical framework of economic complexity (Fraccascia et al., 2018; Hidalgo & Hausmann, 2009) this work will test the hypothesis that services closer to others already green are more likely to become greener.

Fraccascia et al. (2018) suggests that proximity in product or service space may enable diffusion of green productive capabilities, finding that countries are more likely to begin exporting green products that are close to their existing export basket. Transposing this insight to public procurement, one may expect that services that are structurally proximate to already green services would also adopt environmental criteria overtime.

On the other hand, the effect of GPP on the creation of new green products may also suggest that certain dynamics can lead to negative outcomes, largely stemming from market saturation, where the established presence of green products may inhibit the entry of new innovations due to limited market capacity. Bargues et al. (2019) studied the GPP of the Valencian region of Spain have found low weights on the rank of importance of environmental criteria when compared to price, work programs, etc. The authors state the lack of knowledge of the technicians of the contracting agencies on environmental matters may be one of the causes for the low importance of environmental criteria. Additionally, the authors also mention the possibility of non-alignment of the guidelines of the different contracting authorities with European regulations on sustainability.

One can test this hypothesis by adapting the method of Fraccascia et al. (2018) and the method of Ribeiro (2021). The objective is, therefore, to construct a proximity network of services based on shared RCA among suppliers. For each year, perform the

computation of the maximum proximity of each service to other services that were already green in the same year. We then regressed the change in green ratio (i.e., the share of contracts awarded with environmental criteria) between years *t* and *t+1* on the maximum proximity to green services in year *t*.

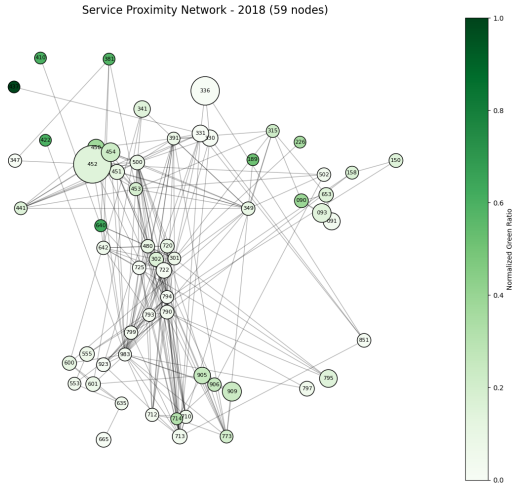
4.1 Network Analysis

Although there are several visualization techniques, for this work, it was decided to use the Kamada-Kawai layout, following the procedure of Ribeiro (2021). This layout is used in undirected graphs (Kamada & Kawai, 1989). Kamada-Kawai layout is a computationally slower and more expensive algorithm, but it does not pose a problem in this specific case. It tries to position nodes in order for their Euclidean distance in the space to be as short as the path distance between them. In order to improve the visualization of the network, the Maximum Spanning Tree (MST) algorithm was chosen, which is the minimum number of edges that maximizes the sum of proximities, ensuring all nodes are interconnected.

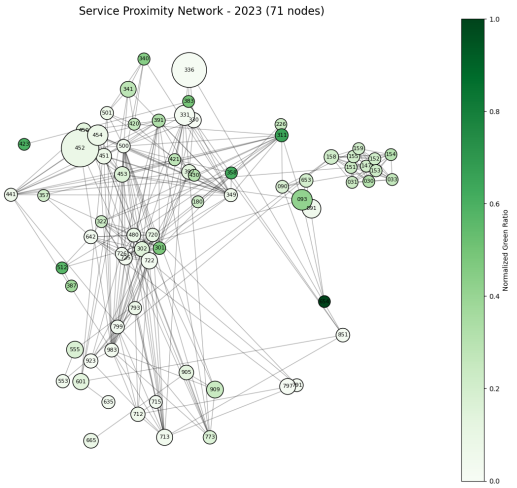
The network was developed in a yearly basis and represents the public procurement service space. Each node in this network represents a Common Procurement Vocabulary (CPV) Level 3 service category. Furthermore, the nodes' size in the network representation is proportional to the sum of contract values associated with the service represented by each node. Additionally, by computing the green ratio, the nodes are colored according to how green the service is.

To ensure interpretability in the level 3 CPV network, in figure 4.1 only the nodes with higher than 10% of green ratio and above the mean value of contract values are represented. Nonetheless, in annex I, are the networks with full representation of CPV codes.

As it is possible to see in figure 4.1, there seems to be a slight increase in the greenness of services. However, it is not completely clear. Furthermore, the increase in green adoption does not seem to be uniformly distributed, because there is no clear clustering effect around already green services. The images in annex I support the broader conclusion that while individual services may green over time, their position in the network does not strongly influence that outcome.



(a) Service Proximity Network - 2018



(b) Service Proximity Network - 2023

Figure 4.1: Networks in 2018 and 2023

Leveraging on the table on annex II, the greenest services in 2018 are, for example, machinery for metallurgy and associated parts (CPV Level 3 437), and machinery for food, beverage and tobacco processing and associated parts (CPV Level 3 422). In 2023, examples of green services are other sources of energy supplies and distribution (CPV Level 3 437), and electric motors, generators and transformers (CPV Level 3 311). Neither of these are related, as can be observed in figure 4.1.

4.2 OLS Regression

This thesis performed a panel OLS regression analysis with Time and Entity Fixed Effects, with the objective of further concluding the effect of green growth when in proximity to green services.

Table 4.1: Correlation Matrix among the variables of the Regression

	GreenGrowth	**log(Volume)**	**ProximityToGreen**
GreenGrowth	1.000		
log(Volume)	0.111	1.000	
ProximityToGreen	-0.400	0.207	1.000

As a first analysis, table 4.1 correlation matrix of all the variables (dependent and independent) was performed. No major correlations are evident.

To verify the assumptions of the classical linear regression model, the model was tested for heteroscedasticity in the residuals using Breusch-Pagan. The results indicated the presence of heteroscedasticity, suggesting that the variance of the error terms is not constant across observations. This violation implies that while the OLS estimates of the coefficients remain unbiased and consistent, the standard errors may be inefficient and lead to unreliable inference (e.g., incorrect p-values or confidence intervals). To address this issue, robust standard errors were employed (i.e., heteroscedasticity-consistent standard errors). Additionally, the model includes fixed time and entity effects.

The OLS regression model is specified as:

$$\begin{aligned}\text{GreenGrowth}_{cst} = \beta_0 + \beta_1 \log(\text{Volume}_{cst}) + \beta_2 \text{ProximityToGreen}_{cst} + \\ + \beta_3(\text{ProximityToGreen}_{cst} \times \log(\text{Volume}_{cst})) + \alpha_c s + \gamma_t + \varepsilon_{cst} \quad (4.1)\end{aligned}$$

Where:

- GreenGrowth_{cst} = is the change in green ratio[1] for service s, for company c, in year t relative to *t-1*
- $\log(\text{Volume}_{cst})$ is the log of total contract value awarded to service s, for company c, in year t
- $\text{ProximityToGreen}_{cst}$ is the maximum proximity of service s, for company c to any green service in year t-1
- $\alpha_c s$ is the service-company fixed effect (entity effect)
- γ_t is the year fixed effect (time effect)
- ε_{cst} is the error term

[1]Green ratio is the ratio between the contracts with environmental criteria and all the contracts for each service

The results of the OLS regression indicate that all of the predictors are statistically significant, with very low p-values, as can be seen in table 4.2. These results have to be interpreted with caution, considering that there is heteroscedasticity in the model, despite its effect being reduced by the measures specified in the previous paragraph.

Table 4.2: OLS Regression Results — Predicting Green Growth
Note: *** p<0.001, ** p<0.01, * p<0.05

Variable	Coef.	Std. Err.
log(Volume)	0.0034***	0.0003
ProximityToGreen	-0.98053***	0.0679
Prox_x_Volume	0.0413***	0.0015

Observations:	37406895
R-squared:	0.4043
F-statistic:	4.819e+06

As can be seen in table 4.2, the R-squared of this model is around 40%. In other words, this model explains about 40% of green growth. On the one hand, it seems that being close to greener services has a negative impact on green growth, since β_2 is negative and the most significant of all the coefficients. Additionally, it is alsp possible to see that the log(Volume) and the interaction between log(Volume) (β_1) and ProximityTo Green (β_3) are both significant with a positive effect on green growth. When the contract value is high, being close to a green service increases the green growth.

These findings suggest that, on average, proximity to green services is not necessarily good for green growth, unless it is paired with high contract values. One possibility for this result is that, as stated by Bargues et al. (2019), there is a lack of knowledge from contracting authorities' technicians or misapplication of regulations. Another explanation may be that of Ghisetti and Rennings (2014), which states that innovations reducing externalities are not profitable, since the cost burden of innovation adoption seems to overcome the potential gains.

Furthermore, Mélon and Spruk (2020) analyses the improvement of public procurement through e-procurement in early adopters including Denmark, the Netherlands, and Portugal. This study also intends to understand if the implementation of e-procurement entails higher institutional quality, which in turn may allow for a wider implementation of green and sustainable procurement. This study's findings present a deterioration of quality in Portugal and a failure in fostering institutional change through the implementation of e-procurement.

4.3 Limitations and Future Work

For this thesis, only an environmental criteria binary flag was used. In Portal BASE platform, since the revision of the Portuguese Public Procurement Law in 2017, a binary flag for environmental criteria was implemented in the data. This simply tells whether there are, or not, environmental criteria in the contract. It does not give any detail on what is the purpose or applicability of environmental criteria in that contract. Therefore, it reduces interpretation of the data to a simple yes or no. Future research could consider the enrichment of the green indicators, possibly incorporating text mining of contract clauses or using external datasets (e.g.: firm-level data) to more accurately classify procurement contracts.

The explanatory power of the model could be improved by including procuring agency characteristics. For example, it does not account for the type of agency that is contracting the service, such as: municipalities, regional government authorities, other public entities, and so on. Other possible variables that could improve the model could be on the supplier-side characteristics, such as: company size, R&D investment, etc.

5

Conclusion

This dissertation aimed to understand whether services that are structurally close to already green services within the Portuguese public procurement landscape are more likely to adopt green criteria over time. By combining a network analysis of service proximity with a panel data regression model, the research assessed how service interdependencies might influence the diffusion of sustainable practices.

The results indicate that proximity to green services alone does not inherently lead to greater green adoption. In fact, a negative relationship was observed between proximity and green growth. However, this relationship shifts positively when proximity is coupled with higher contract values. These findings suggest that the structural closeness of services is not a sufficient driver of green diffusion, having economic scale or investment magnitude play a moderating role.

The network visualizations over time show a modest increase in green contract adoption but do not exhibit clear clustering effects or consistent patterns linked to service proximity. The regression analysis reinforced this by showing that only when substantial contract volumes are involved does proximity contribute positively to green growth.

Limitations related to data granularity, such as the binary nature of the environmental criteria flag and the exclusion of agency-specific or supplier-level attributes, highlight potential avenues for future work. Enhancing the granularity of green metrics and incorporating more contextual variables could refine the explanatory power of the model and lead to deeper insights.

In summary, the study provides a nuanced understanding of how green practices emerge in public procurement. It emphasizes that structural proximity within procurement networks, while relevant, is not a standalone driver of sustainable transition. Strategic investment and targeted policy support may be required to effectively

leverage service interconnections for green growth.

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I

Annex 1 Network Representations from 2018 to 2023

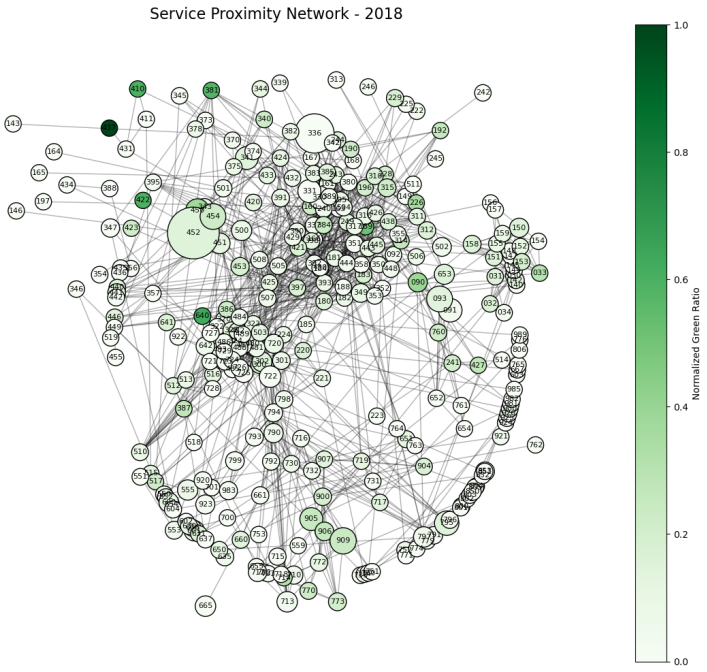

Figure I.1: Network Representation 2018

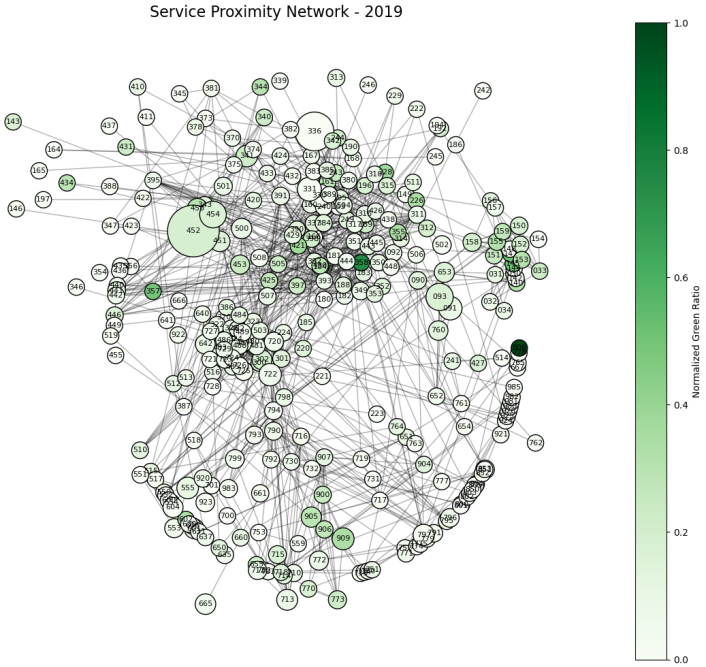

Figure I.2: Network Representation 2019

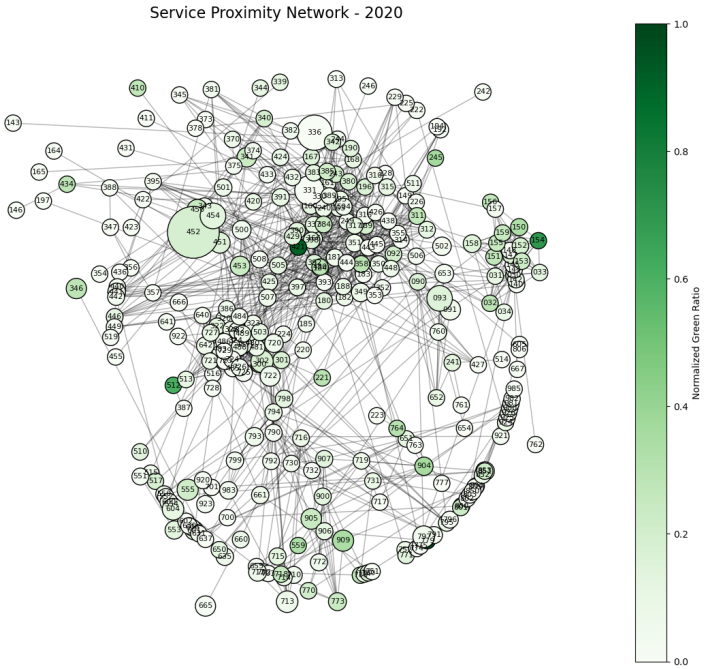

Figure I.3: Network Representation 2020

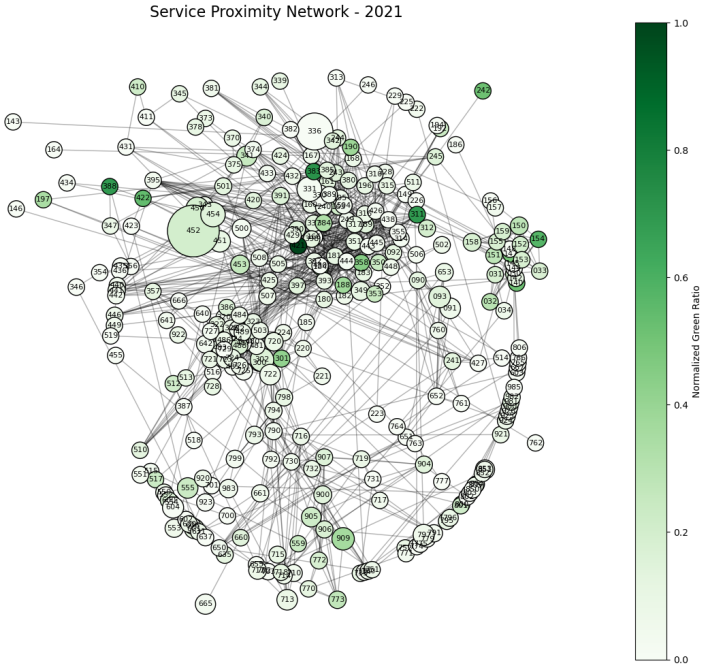

Figure I.4: Network Representation 2021

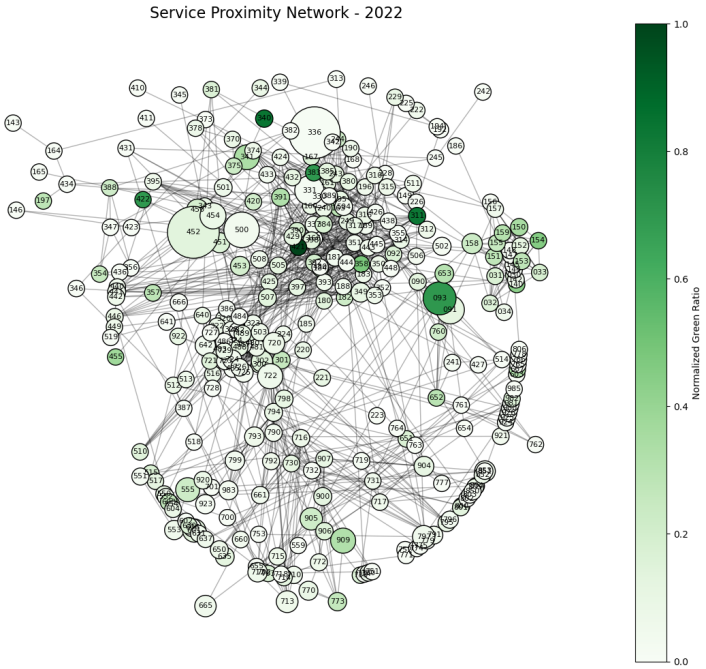

Figure I.5: Network Representation 2022

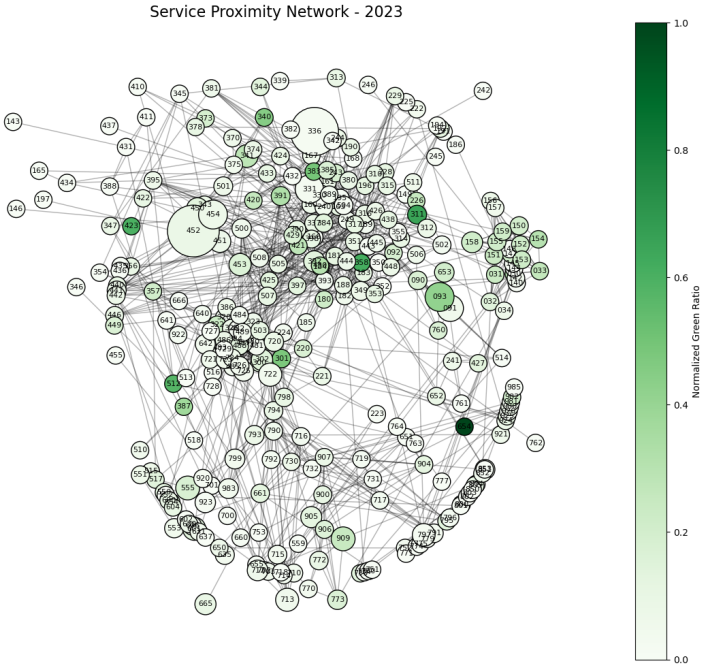

Figure I.6: Network Representation 2023

II

Annex 2 CPV Level 2 Mapping

Table II.1: CPV Level 2 Mapping between Codes and Description

Code	Description
031	Agricultural and horticultural products.
032	Cereals, potatoes, vegetables, fruits and nuts.
033	Farming, hunting and fishing products.
034	Forestry and logging products.
091	Fuels.
092	Petroleum, coal and oil products.
093	Electricity, heating, solar and nuclear energy.
142	Sand and clay.
143	Chemical and fertiliser minerals.
144	Salt and pure sodium chloride.
145	Related mining and quarrying products.
145	Precious and semi-precious stones; pumice stone; emery; natural abrasives; other minerals and precious metals.
146	Metal ores and alloys.
147	Basic metals.
148	Miscellaneous non-metallic mineral products.
149	Recovered secondary raw materials.
151	Animal products, meat and meat products.
152	Prepared and preserved fish.
153	Fruit, vegetables and related products.
154	Animal or vegetable oils and fats.
155	Dairy products.
156	Grain mill products, starches and starch products.
157	Animal feedstuffs.
158	Miscellaneous food products.
159	Beverages, tabacco and related products.

Code	Description
161	Agricultural and forestry machinery for soil preparation or cultivation.
163	Harvesting machinery.
164	Spraying machinery for agriculture or horticulture.
165	Self-loading or unloading trailers and semi-trailers for agriculture.
166	Specialist agricultural or forestry machinery.
167	Tractors.
168	Parts of agricultural and forestry machinery.
181	Occupational clothing, special workwear and accessories.
182	Outerwear.
183	Garments.
184	Special clothing and accessories.
185	Jewellery, watches and related articles.
186	Furs and articles of fur.
188	Footwear.
189	Luggage, saddlery, sacks and bags.
191	Leather.
192	Textile fabrics and related items.
194	Textile yarn and thread.
195	Rubber and plastic materials.
196	Leather, textile, rubber and plastic waste.
197	Synthetic rubber and fibres.
221	Printed books, brochures and leaflets.
222	Newspapers, journals, periodicals and magazines.
223	Postcards, greeting cards and other printed matter.
224	Stamps, cheque forms, banknotes, stock certificates, trade advertising material, catalogues and manuals.
225	Printing plates or cylinders or other media for use in printing.
226	Ink.
228	Paper or paperboard registers, account books, binders, forms and other articles of printed stationery.
229	Miscellaneous printed matter.
241	Gases.
242	Dyes and pigments.
243	Basic inorganic and organic chemicals.
244	Fertilisers and nitrogen compounds.
245	Plastics in primary forms.
246	Explosives.
249	Fine and various chemical products.

Code	Description
301	Office machinery, equipment and supplies except computers, printers and furniture.
302	Computer equipment and supplies.
311	Electric motors, generators and transformers.
312	Electricity distribution and control apparatus.
313	Insulated wire and cable.
314	Accumulators, primary cells and primary batteries.
315	Lighting equipment and electric lamps.
316	Electrical equipment and apparatus.
317	Electronic, electromechanical and electrotechnical supplies.
322	Transmission apparatus for radiotelephony, radiotelegraphy, radio broadcasting and television.
323	Television and radio receivers, and sound or video recording or reproducing apparatus.
324	Networks.
325	Telecommunications equipment and supplies.
331	Medical equipments.
336	Pharmaceutical products.
337	Personal care products.
339	Postmortem and mortuary equipment and supplies.
341	Motor vehicles.
342	Vehicle bodies, trailers or semi-trailers.
343	Parts and accessories for vehicles and their engines.
344	Motorcycles, bicycles and sidecars.
345	Ships and boats.
346	Railway and tramway locomotives and rolling stock and associated parts.
347	Aircraft and spacecraft.
349	Miscellaneous transport equipment and spare parts.
351	Emergency and security equipment.
352	Police equipment.
353	Weapons, ammunition and associated parts.
354	Military vehicles and associated parts.
355	Warships and associated parts.
356	Military aircrafts, missiles and spacecrafts.
357	Military electronic systems.
358	Individual and support equipment.
373	Musical instruments and parts.
374	Sports goods and equipment.

Code	Description
375	Games and toys; fairground amusements.
378	Handicraft and art supplies.
381	Navigational and meteorological instruments.
382	Geological and geophysical instruments.
383	Measuring instruments.
384	Instruments for checking physical characteristics.
385	Checking and testing apparatus.
386	Optical instruments.
387	Time registers and the like; parking meters.
388	Industrial process control equipment and remote-control equipment.
389	Miscellaneous evaluation or testing instruments.
391	Furniture.
392	Furnishing.
393	Miscellaneous equipment.
395	Textile articles.
397	Domestic appliances.
398	Cleaning and polishing products.
411	Natural water.
421	Machinery for the production and use of mechanical power.
422	Machinery for food, beverage and tobacco processing and associated parts.
423	Industrial or laboratory furnaces, incinerators and ovens.
424	Lifting and handling equipment and parts.
425	Cooling and ventilation equipment.
426	Machine tools.
427	Machinery for textile, apparel and leather production.
428	Machinery for paper or paperboard production.
429	Miscellaneous general and special-purpose machinery.
431	Mining equipment.
432	Earthmoving and excavating machinery, and associated parts.
433	Construction machinery and equipment.
434	Mineral-processing and foundry mould-forming machinery.
435	Track-laying vehicles.
436	Parts of machinery for mining, quarrying and construction.
437	Machinery for metallurgy and associated parts.
438	Workshop equipment.
441	Construction materials and associated items.
442	Structural products.
443	Cable, wire and related products.

Code	Description
444	Miscellaneous fabricated products and related items.
445	Tools, locks, keys, hinges, fasteners, chain and springs.
446	Tanks, reservoirs and containers; central-heating radiators and boilers.
448	Paints, varnishes and mastics.
449	Stone for construction, limestone, gypsum and slate.
451	Site preparation work.
452	Works for complete or part construction and civil engineering work.
453	Building installation work.
454	Building completion work.
455	Hire of construction and civil engineering machinery and equipment with operator.
481	Industry specific software package.
482	Networking, Internet and intranet software package.
483	Document creation, drawing, imaging, scheduling and productivity software package.
484	Business transaction and personal business software package.
485	Communication and multimedia software package.
486	Database and operating software package.
487	Software package utilities.
488	Information systems and servers.
489	Miscellaneous software package and computer systems.
501	Repair, maintenance and associated services of vehicles and related equipment.
502	Repair, maintenance and associated services related to aircraft, railways, roads and marine equipment.
503	Repair, maintenance and associated services related to personal computers, office equipment, telecommunications and audio-visual equipment.
504	Repair and maintenance services of medical and precision equipment.
505	Repair and maintenance services for pumps, valves, taps and metal containers and machinery.
506	Repair and maintenance services of security and defence materials.
507	Repair and maintenance services of building installations.
508	Miscellaneous repair and maintenance services.
511	Installation services of electrical and mechanical equipment.
512	Installation services of equipment for measuring, checking, testing and navigating.
513	Installation services of communications equipment.
514	Installation services of medical and surgical equipment.

Code	Description
515	Installation services of machinery and equipment.
516	Installation services of computers and office equipment.
517	Installation services of fire protection equipment.
518	Installation services of metal containers.
519	Installation services of guidance and control systems.
551	Hotel services.
552	Camping sites and other non-hotel accommodation.
553	Restaurant and food-serving services.
554	Beverage-serving services.
555	Canteen and catering services.
559	Retail trade services.
601	Road transport services.
602	Railway transport services.
603	Pipeline transport services.
604	Air transport services.
605	Space transport services.
606	Water transport services.
631	Cargo handling and storage services.
635	Travel agency, tour operator and tourist assistance services.
637	Support services for land, water and air transport.
641	Post and courier services.
642	Telecommunications services.
651	Water distribution and related services.
652	Gas distribution and related services.
653	Electricity distribution and related services.
654	Other sources of energy supplies and distribution.
655	Meter reading service.
661	Banking and investment services.
665	Insurance and pension services.
666	Treasury services.
667	Reinsurance services.
701	Real estate services with own property.
702	Renting or leasing services of own property.
703	Real estate agency services on a fee or contract basis.
712	Architectural and related services.
713	Engineering services.
714	Urban planning and landscape architectural services.
715	Construction-related services.
716	Technical testing, analysis and consultancy services.

Code	Description
717	Monitoring and control services.
718	Consulting services for water-supply and waste consultancy.
719	Laboratory services.
721	Hardware consultancy services.
722	Software programming and consultancy services.
723	Data services.
724	Internet services.
725	Computer-related services.
726	Computer support and consultancy services.
727	Computer network services.
728	Computer audit and testing services.
729	Computer back-up and catalogue conversion services.
731	Research and experimental development services.
732	Research and development consultancy services.
733	Design and execution of research and development.
734	Research and Development services on security and defence materials.
751	Administration services.
752	Provision of services to the community.
753	Compulsory social security services.
761	Professional services for the gas industry.
762	Professional services for the oil industry.
763	Drilling services.
764	Rig-positioning services.
765	Onshore and offshore services.
766	Pipeline-inspection services.
771	Agricultural services.
772	Forestry services.
773	Horticultural services.
774	Zoological services.
775	Animal husbandry services.
776	Hunting services.
777	Services incidental to fishing.
778	Aquaculture services.
779	Apiculture services.
791	Legal services.
792	Accounting, auditing and fiscal services.
793	Market and economic research; polling and statistics.
794	Business and management consultancy and related services.
795	Office-support services.

Code	Description
796	Recruitment services.
797	Investigation and security services.
798	Printing and related services.
799	Miscellaneous business and business-related services.
801	Primary education services.
802	Secondary education services.
803	Higher education services.
804	Adult and other education services.
805	Training services.
806	Training services in defence and security materials.
851	Health services.
852	Veterinary services.
853	Social work and related services.
904	Sewage services.
905	Refuse and waste related services.
906	Cleaning and sanitation services in urban or rural areas, and related services.
907	Environmental services.
909	Cleaning and sanitation services.
921	Motion picture and video services.
922	Radio and television services.
923	Entertainment services.
924	News-agency services.
925	Library, archives, museums and other cultural services.
926	Sporting services.
927	Cybercafé services.
981	Membership organisation services.
982	Equal opportunities consultancy services.
983	Miscellaneous services.
985	Private households with employed persons.
989	Services provided by extra-territorial organisations and bodies.

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