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The Effect of Public Procurement by Category on Innovation Output

A Fixed Effects Model using Driscoll and Kraay Standard Errors on
Municipal Data in Portugal

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Dissertation

presented as partial requirement for obtaining the Master's Degree Program in Statistics and Information Management

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

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**THE EFFECT OF PUBLIC PROCURMENT BY CATEGORY ON
INNOVATION OUTPUT**

By

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Master requirement for obtaining the Master's degree in Statistics and Information Management,
with a specialization in Information Management

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November 2022

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.

ABSTRACT

When the government and other public sector entities purchase works, goods or services, it is referred to as public procurement. Although there appears to be an increase in the study of public procurement, there is still a lot to discover that could aid policymakers in their economic decision-making-processes. This thesis adds to past studies by exploring the relationship between public procurement and innovation output at a municipal level in Portugal. A fixed effects model with Driscoll-Kraay standard errors was performed to research the innovation output. The final model suggests that the elasticity of innovation with respect to public procurement in services is negative, which can be explained through many zero or low-innovation outputs in the dataset. Furthermore, the work-related public procurement was shown to be negative but with positive marginal effects while also depending positively on population. Therefore, faster growing municipalities can spend less money on public procurement in works than municipalities that grow at a slower pace to reap the same innovation outcomes.

KEYWORDS

Public procurement; Regional innovation policy; Innovation; Innovation-oriented public procurement

Sustainable Development Goals (SGD):



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LIST OF ABBREVIATIONS AND ACRONYMS

ANI	<i>Agência Nacional de Inovação</i>
DOD	Department of Defense
IMPIC	<i>Instituto dos Mercados Públicos, do Imobiliário e da Construção</i>
GDP	Gross Domestic Product
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
R&D	Research and Development
SME	Small and medium enterprises

1. INTRODUCTION

Public procurement occurs whenever an entity from the public sector purchases any type of works, goods or services. These expenditures take up a big part of governmental expenses. According to the Organization for Economic Cooperation and Development (OECD, 2017), public procurement expenses account for 29% of total public spending among OECD countries. Given its considerable share, public procurement should be well-studied and well-allocated to make the most out of the money spent. In fact, as further explained below, if used efficiently, public procurement can be a powerful tool to help the targeted development and shaping of regions and countries. Portugal, in particular, showed great differences in terms of development by region (OECD, 2008) which could theoretically be minimized with the help of public procurement. So naturally, it is in the best interest of governments from not only a monetary, but also an economic and social perspective, to allocate these funds as efficiently as possible. It is crucial, therefore, that public procurement is carefully studied and analyzed.

Guerzoni and Raiteri (2015, p. 729) describe innovative public procurement as “the purchasing activities carried out by public agencies that may lead to innovation”. In this vein, studies have long shown how the use of public procurement can increase a country’s competitive advantages by demanding novel and advanced products and services early on and, thus, not only encouraging competition but also innovation (Porter, 2019). Moreover, it has been argued that public entities can encourage the development of innovative solutions in the private market through demanding and purchasing said solutions (Tsipouri, 2015). However, Georghiou et al. (2014) highlight that there is a lack of theoretical and empirical research done on how policy design can influence such procurement for innovation. It further appears that although there has been research done on innovation-oriented public procurement, there is still much to discover at a regional level (Uyarra, 2020). This thesis aims to add to past studies done on the subject by exploring whether there is a link between the amount municipalities in Portugal spend on public procurement and their respective innovative outputs in Portugal on a municipal level and whether these impacts are different across the three procurement categories: works, goods and services. In consequence, I believe this research will help understand public procurement better and thus take a step further into aiding policymakers in their decision-making process when it comes to the allocation of their public procurement funds in relation to innovation.

To be able to account for the differences within each municipality, the final dataset was constructed to be of longitudinal nature. In the end, a fixed effects model was performed with Driscoll-Kraay standard errors as the panel data shows to have cross-sectional dependence. The model suggests that there is a negative elasticity of innovation with respect to public procurement in services of 1.3. As explained below, this does not have to translate into municipalities decreasing their innovation output when they invest in service-related public procurement. In contrary, given the dataset, there might be more municipalities with zero or low-innovation output that could lead to the negative elasticity. The final model further

suggests that the effects of public procurement in works are negative but with positive marginal effects and that they depend positively on population as well. Thus, faster growing municipalities can spend lower amounts on work-related contracts to get the same impacts on innovation as slower growing municipalities.

2. LITERATURE REVIEW

There appear to be two main streams of literature that discuss governmental spending and innovation from different points of view. The first one explores how governments push innovation through more targeted spending, while the second, and seemingly more recent one, takes a closer look at public procurement that, in itself, has innovation as a goal. Both are important as they might give insights on the links between governmental spending and innovation.

2.1. TARGETED GOVERNMENTAL SPENDING ON INNOVATION

Although this first stream does not necessarily talk about public procurement itself, it can be of aid in understanding the effects governmental spending has in general on innovation. As public procurement is a form of such expenses, this gives a guideline on what to expect.

In a first study, Romero-Martínez, Ortiz-de-Urbina-Criado and Ribeiro Soriano (2010) examine how funding provided by the European Union is being used by Spanish small and medium enterprises (SME), with a focus on firms in the service sector. They find that although many ways of funding have been made available, only a small fraction of firms actually takes advantage of them, although exploiting these funding opportunities would be in their interest. These findings are interesting to keep in mind due to three main reasons. First, even though innovation funding might be available, that does not have to translate into firms taking advantage of these opportunities. Big, unexplainable disparities between municipalities might be due to miscommunication or asymmetric information. Although this is to some level controlled for in this study, it remains an interesting point in understanding dissimilarities between regions. Secondly, this study looks at small and medium firms in particular which leads to the question of whether bigger firms do take advantage of these funds or not. For this reason and others mentioned below, the number of large corporations as well as the number of SMEs has been added to our dataset as controls. A third reason why this study is particularly interesting is that it looked at the service sector. As the dataset includes public procurement for service, goods and works, this thesis adds a layer to the study by comparing other sectors with innovation data.

As innovation can be costly for firms, Bhattacharya (2018) studied research and development (R&D) contests for a procurement contract by analyzing the Department of Defense's (DOD) Small Business Innovation Research program. He concluded that since the DOD pays for the research but cannot fully reap the gains from the contest's innovation, they have an incentive to not pick the socially optimal design. Increasing the number of late-stage competitors, lowering the firms' share of the procurement surplus and instructing that firms share intellectual property would be examples that would increase total social surplus but might decrease the DOD's profits from the contests. As the DOD is a public entity, this study is of high value for this thesis as it shows an incentive for municipalities to not operate as

efficiently as they could. Below the importance of trust in the public purchaser is further analyzed.

2.2. PUBLIC PROCUREMENT OF INNOVATION

To understand public procurement, it is crucial to be aware of its limitations as well. One big challenge for public procurement of innovation is that, compared to the private sector, public contracts must conform to particular legal and regulatory frameworks. This is also among the reasons why there has been a decline in overall public procurement until the mid-2000s when demand-side public procurement of innovation gained more interest in some EU Member States (Edquist et al., 2000; Edler et al., 2006). Furthermore, it has been argued that a key condition for public procurement of innovation is that they follow a systematic, open, transparent, and objective process (Edler, 2010). Hollanders and Arundel (2007) further highlight this by showing how 'trust' and 'corruption' strongly correlate with innovation output. In other words, competing entities must feel that the best value which meets the clear contract criteria succeeds and that there was no corruption, bribery or similar aspects that influenced the decision-making process of the public purchaser. As with different elections might come more or less corrupt governments, this is something that was not able to be controlled for using the fixed effects model as it might not be time-invariant. However, it can be an explanation why otherwise similar regions might have different public procurement of innovation performances.

Governments have had an impact on private R&D through not only an existing functional intellectual property rights system, but also through tax credits and direct subsidies for private innovation projects (Dechezleprêtre, Einiö, Martin, Nguyen, Van Reenen, 2016; Einiö, 2014; Howell, 2017; Hünermund and Czarnitzki, 2019). However, demand-sided governmental influence, such as public procurement of innovation, has particularly gained more attention in the past few years (EFI 2013; OECD, 2017; Slavtchev and Wiederhold, 2016) although it has long been suggested that state procurement can stimulate innovation better than R&D subsidies could at the time (Rothwell and Gardiner, 1989; Geroski, 1990, p. 183).

In contrast to traditional supply-side innovation policies, public procurement of innovation leads to an increased demand for innovative products and services. Consequently, the expected profits from these contracts indirectly incentivize firms to invest in their R&D (Schmookler, 1966; Acemoglu and Linn, 2004; Slavtchev and Wiederhold, 2016). Furthermore, Frenken (2017) and Grillitsch et al. (2019) have found that through public procurement, demand is being articulated leading to an increase in the chances of innovation not only being accepted, but also adopted and therefore sculpturing and legitimating the innovation procedure to cope with the complexities of contemporary innovation. From a governmental perspective, certain policy goals may be targeted through public procurement for innovation as, for example, energy sustainability and effectiveness, environmental preservation (De Marchi, 2012; Constantini et al., 2015) or providing healthcare for an elder population (Uyarra et al., 2020).

Another liked, yet different aspect related to innovations that stem from public procurement, is that they tend to be incremental in nature and not radical (Czarnitzki et al., 2020). This can be explained as incremental innovations are associated with a lower development risk which in turn makes the procurement contract more easily enforceable (Bruce, de Figueiredo and Silverman 2019). Furthermore, incremental innovations tend to be more easily describable and controllable which plays in favor of public procurement (Edler, Rolfstam, Tsipouri and Uyarra, 2015). Although this is something that was not included in the model, it allows for a deeper understanding of public procurement of innovation.

There have been two broad distinctions in procured governmental innovations. The first innovation class describes products and services for which the public entity is the only end-user and the second one describes innovations that have a significant use outside of the public realm. A well-studied example for the first class is military procurement. An important subclass within this second group is *catalytic* public procurement, where the buying entity aims “to catalyse the development of innovations for broader public use” rather than merely its own (Edquist and Zabala-Iturriagagoitia, 2012). In this type of procurement, the government acts as a lead user for innovations and creates network effects that pave way for developments in private markets (Von Hippel, 1986; Dalpé, DeBresson, and Xiaoping, 1992; De Chiara and Iossa, 2019; Czarnitzki, Hünermund, and Moshgbar, 2020). A relevant term here is *deep coordination* where in addition to creating demand, potential regulatory and institutional adaptations are made to favor the emergence of the innovation at hand (Bleda and Chicot, 2020). These changes are more exigent the more complex and less related to existing economic works the innovation is, which in turn complicates the knowledge exchange between cognitively, and frequently geographically, distant parties (Balland et al., 2019; Uyarra et al., 2020). As this thesis looks at regional data, this is a factor to keep in mind.

Unfortunately, the previous legal framework did not allow for specifications of not yet invented or developed products or services in procurement contracts. It was only in 2014 that the European Commission changed their public procurement regulations to offer not only functional, but also performance-based specifications in their public contracts to promote innovation. These 2014/24/EU and 2014/25/EU directives were supposed to be translated into national laws by 2016 (European Commission, 2015). To test the efficiency of this law, a 2020 study was done by Czarnitzki, Hünermund, and Moshgbar. There, they analyzed over three thousand German firms from 2010 to 2012 as Germany is seen as a forerunner in public procurement of innovation. The reason being that in 2009 Germany had enforced a legislature very similar to the one by the European Union, so sufficient data was available from the Community Innovation Surveys. The main findings were that firms which had a public procurement contract within the years of 2010 and 2012 showed a positive and significant change in turnover in new products, as well as new-to-firm novelties. However, new-to-market novelties did not show to have been impacted by public procurement. As the legal framework has, thus, changed in Portugal as well, it might be of interest to examine whether there is an observable change of innovation in later contracts that could be attributed to this

new law. However, I expect it to be too soon to spot any accountable changes yet. It is, nevertheless, something to look out for especially for future studies regarding public procurement and innovation in Portugal.

2.3. PUBLIC PROCUREMENT OF INNOVATION BY REGION

As I will be exploring Portuguese public procurement data, a study of particular interest to this thesis was made by Curado, Damásio, Encarnação, Candia and Pinheiro (2021) where Portuguese contracts are closely analyzed in relation to municipal population size using Urban Scaling Laws. They found that larger municipalities are more efficient as they spend proportionally less than linear scaling would predict. By doing so, public procurement activity exhibits economies of scale. They further discover that this efficiency is different across the three types of contracts, works, goods and services.

Knowing that public procurement performs differently according to population size is important as it might also be the case that larger municipalities might not need to spend as much as linearly predicted compared to smaller ones to get the same innovative output. Reasons for this can be that, besides the general benefits of founding a company in a bigger city, for example, having a larger and thus more diverse working pool, if a municipality invests a lot in their economic growth through public procurement, this can theoretically be an additional incentive for firms to be founded in said region. By doing so, a cluster of firms is created which has been shown to be advantageous for the innovation process through, for instance, the creation of local buzz where opportunities are created due to a variety of unanticipated interactions and the forming of interpretative communities (Nonaka et al., 2000; Bathelt et al., 2004). Moreover, it has long been known that physical, social and economic geographical concentration of not only competing but also cooperating companies are shown to facilitate learning, innovation and competitiveness through interpersonal and institutionalized networks (Porter, 1998, 2011). These studies on geographical advantages paved the way for the Regional Innovation Systems approach, which focuses on building innovation policies on a regional rather than national basis with an emphasis on the knowledge flows between a myriad of variables and stakeholders of a regional system (Cooke et al., 1999; Asheim and Gertler, 2005; Vecchiato and Roveda, 2014).

In a similar vein, Tammi et al. (2020) investigated the effects competition has on innovation and how this is related to SME behavior in public procurement. They found that in regions with low initial levels of competitiveness, an increase in competition tends to lead to an increase in innovation orientation whereas, on the contrary, with high initial levels of competitiveness, an increase in competition was shown to reduce innovation. Intermediate levels of competitiveness are associated with high innovation orientations. Combining this with the studies mentioned above, it can be assumed that bigger municipalities might show smaller outputs in innovation when competition is increased through public procurement contests while in smaller municipalities the effect would be the opposite and innovation could be fostered more efficiently. This research also showed that SME were less innovation-

oriented if they mainly supplied to public sector customers within their own municipality, compared to SME who mainly supplied to public sector customers outside their regions.

3. METHODOLOGY

3.1. DATA AND DESCRIPTIVE STATISTICS

Since 2008, all Portuguese public administration bodies are legally obliged to publish their procurement activity online through BASE (Ministério das Obras Públicas, 2008; Costa A. A. et al., 2013). BASE is a governmental open-access public repository managed by the *Instituto dos Mercados Públicos, do Imobiliário e da Construção* (IMPIC) and for this analysis Portuguese public procurement between 2019 and 2022 was sourced from dados.gov, the Portuguese portal of open data. This was added to a dataset by Curado et al. (2021) which included all contracts from 2009 to 2018. The data consists of contracts issued by the 278 continental Portuguese municipalities. As the Azores and Madeira represent autonomous administrative regions, their municipalities were not taken into consideration for this research. The contracts were summed by year into each of the three procurement categories: goods, services and works. In total, Portuguese municipalities spent the most amount on work-related public procurement, then services and the least in goods. However, the most contracts are issued for services, then goods and lastly, the least number of contracts are issued for work-related public procurement suggesting that these work contracts are of higher value than the other two. A total across all years by Portuguese districts can be seen in figures one to three below.

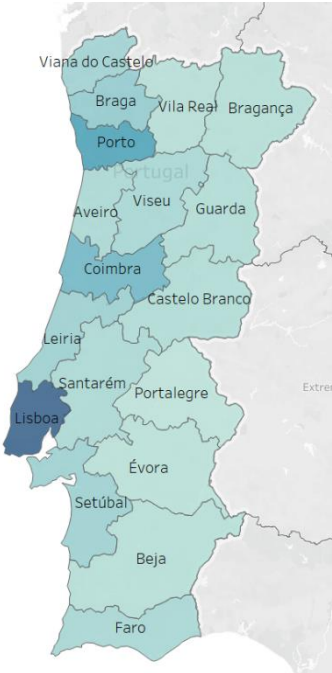


Figure 1: Public Procurement in Goods across Portugal from 2009 to 2022

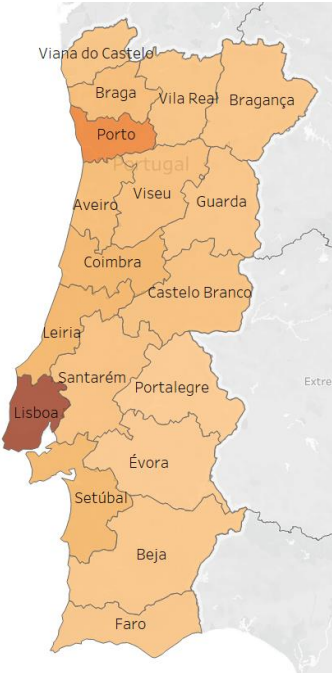


Figure 2: Public Procurement in Services across Portugal from 2009 to 2022



Figure 3: Public Procurement in Works across Portugal from 2009 to 2022

From the maps above, it can rapidly be seen that the capital, Lisbon, and Porto show the biggest share of spending in public procurement across all categories which does not come as a surprise given their importance as cities in Portugal. One thing to note is that coastal

regions show a slightly higher spending amount across categories than inland regions. These procurement variables, each category and the respective number of contracts issued, were transformed into natural logarithms and their quadratic terms were added into the dataset. This was done to better capture the datapoints as shown in the appendix.

The public procurement data was merged with open innovation data from 2009 to 2022 sourced from the *Agência Nacional de Inovação* (ANI, ani.pt), the national innovation agency of Portugal which is further supported by the European Regional Development Fund. The data captures not only a myriad of innovation-related projects but the data can also be merged to show the spending at a municipal level, making it particularly useful for this thesis. For projects which had various co-promoters from different municipalities, the total amount was split equally among all participating regions.

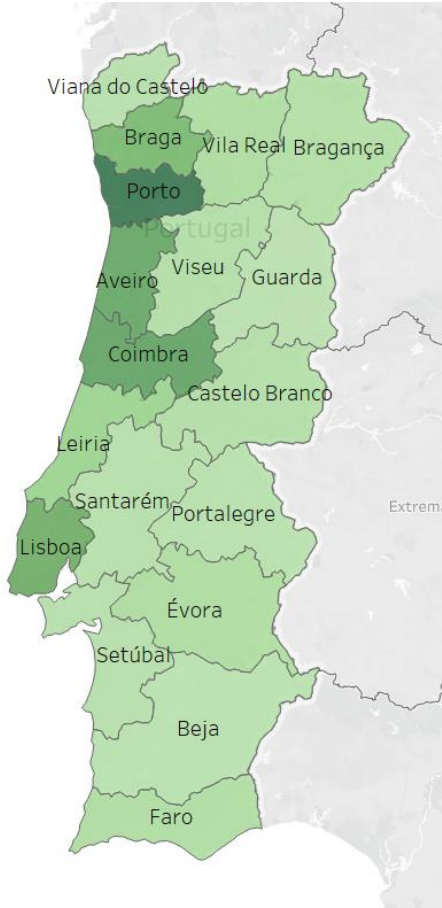


Figure 4: Innovation across Portugal from 2009 to 2022

In figure 2, the total amount of innovation output in the years of 2009 to 2022 can be observed. Unlike public procurement, the innovation output is not only the strongest in Lisbon and Porto but is centered in the coastal North.

To complete the dataset, control variables were added sourced from PORDATA (pordata.pt), the Contemporary Portugal Database with official and certified statistics about Portugal. To account for the size of each municipality and for the reasons explained in the literature above, the population size was added as a control. Furthermore, based on the above-mentioned research, the number of higher education establishments and the number of SME as well as large corporations were incorporated into the dataset. Moreover, the average monthly salaries were included as Bleaney and Wakelin (2002) suggested that innovators pay higher salaries and to, to some extent, reflect the educational level of the

municipality’s workforce as they did in their study. The expenses and revenue of each municipality were added to mimic the municipal gross domestic product (GDP) that were not open publicly. These were added due to the fact that the innovation of a region depends on the development of the GDP as suggested by Gössling and Rutten (2007). For variables where there was insufficient data for the latest years, a forecast based on a linear regression was

used to predict the missing values. As shown in the appendix, to better fit the data, the natural logarithm of all controls was taken except for Population, average monthly salary and the number of large corporations where adding a quadratic term was the better option. Moreover, as Curado et al. (2021) suggest that public procurement scales sublinearly with population and thus, showing economies of scale, an interaction term for each of the procurement categories with population was added, both in natural logarithms.

In the end, the dataset is a balanced panel dataset which consists of 14 years for each of the 278 municipalities, so a total of 3892 observations. An evolution of the sum of each of the three procurement categories and our dependent variable, innovation, across the years 2009 to 2022 can be observed in figure five below.

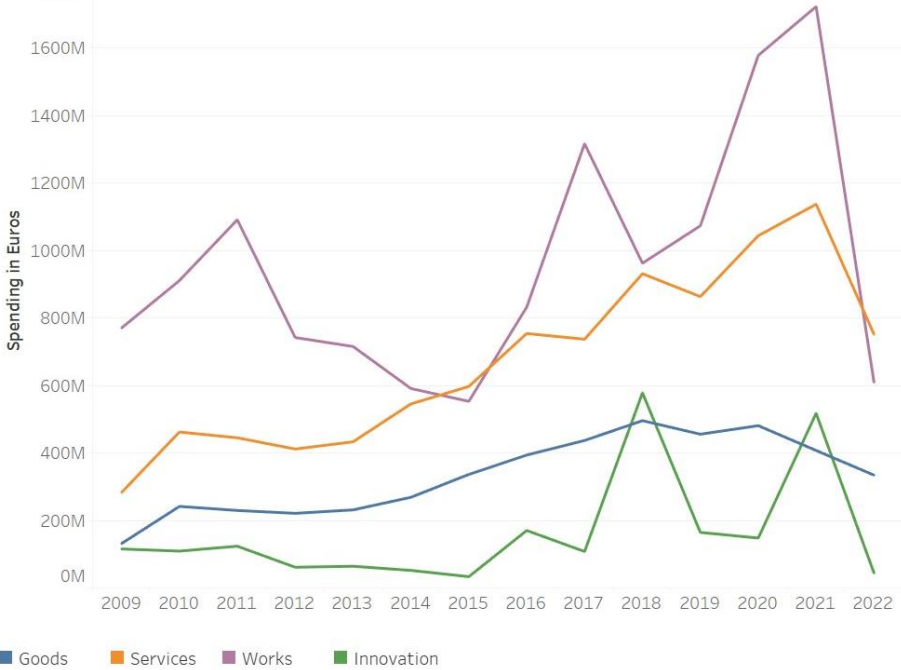


Figure 5: Evolution of Procurement Categories and Innovation from 2009 to 2022

This initial illustration helps get a better grasp of the data at hand, suggesting an overall upwards trend for all four variables. It furthermore highlights the differences in spending amounts, showing that, overall, innovation spending is of a much lower value. Furthermore, to understand how the innovation related to procurement categories across municipalities, their ratio was taken per year and illustrated as an average in figures six to eight below.

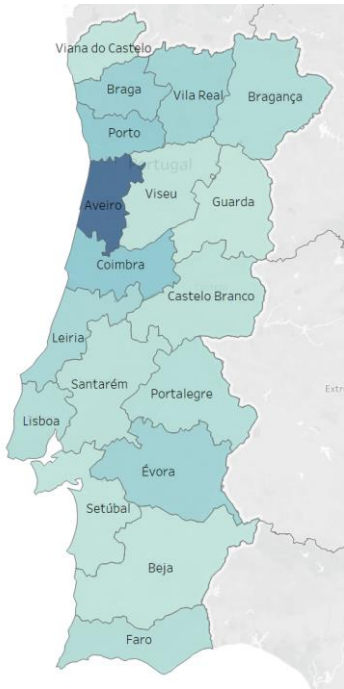


Figure 6: Average Innovation Output to Public Procurement in Goods Ratio from 2009 to 2022 per District

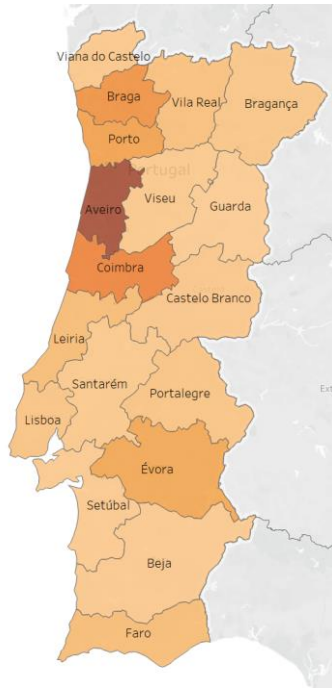


Figure 7: Average Innovation Output to Public Procurement in Services Ratio from 2009 to 2022 per District

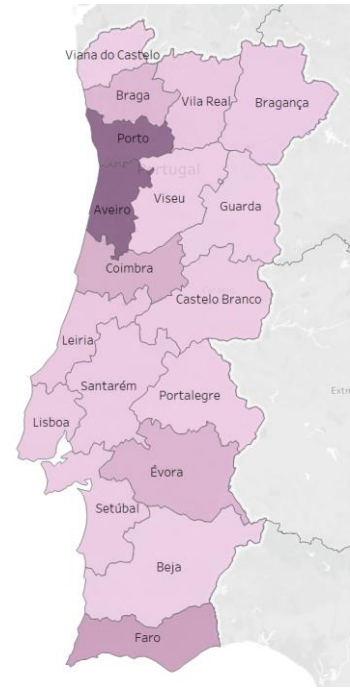


Figure 8: Average Innovation Output to Public Procurement in Works Ratio from 2009 to 2022 per District

Rapidly, Aveiro stands out by having the highest innovation-to-procurement-ratios across all procurement categories. Moreover, there appears to be an overall higher average ratio in the coastal north as well as in Évora and Faro. These illustrations propose an interesting starting point for future research as the noted districts might show different characteristics that can help explain these findings.

4. EMPIRICAL STUDY

The public procurement as well as dependent variables were tested for stationarity using the Augmented Dickey-Fuller Test seen in the appendix. All seven variables, the three categories and their respective number of contracts as well as total investment in innovation, were stationary. As the dataset is of longitudinal nature, it can control for unobservable variables within each municipality and account for municipal heterogeneity. It also allows controlling for variables that change over time but not across municipalities, which is the reason why certain variables were not included, such as dummies concerning election years or COVID-19.

4.1. PANEL DATA ESTIMATION

The final model that was opted for is a fixed effects model which statistically showed to be the best fitted model for the data at hand as shown below. By using fixed effects, time-invariant characteristics within each municipality are removed, so that the net effects of public procurement on innovation can be explored. In other words, this allows to control for municipality specific traits, where in different models there could have been an omitted variable bias. Such variables were mentioned in the literature above and include, for instance, municipal culture and religion.

4.1.1. Hausman Specification Test

As random effects could be a preferable model, a Hausman Specification Test was performed, specified to be less likely to produce non-positive-definite-difference covariance matrices. Furthermore, the matrices are based on the same estimated disturbance variances from the efficient estimator. The null hypothesis, that the random model is the preferred model, was rejected at the 1% level with a chi-squared statistic of 299.85 as seen in the appendix. Therefore, the fixed effects remained better fitted to describe our data.

4.1.2. Cross-Municipality Dependence

Since the data is sourced from Portuguese municipalities, it can be assumed that municipalities share some dependence with each other. Therefore, it is of utmost importance to check for cross-sectional dependence as otherwise there could be biased test results with contemporaneous correlation. To do so, a Pasaran Cross-Sectional Dependence Test was performed where the null hypothesis is that residuals are not correlated across municipalities. As expected, the null hypothesis was rejected at the 1% significance level and, thus, there is cross-municipal dependence. In order to account for this, Driscoll and Kraay standard errors were used for the final model as suggested by Hoechle (2007). These standard errors are heteroskedasticity consistent and robust to spatial as well as temporal dependence. Considering a linear regression model with

$$y_{it} = x'_{it}\beta + v_{it}, \quad i = 1, \dots, 278 \text{ (municipalities)}, \quad t = 1, \dots, 14 \text{ (years)}$$

where y_{it} is a scalar, y , of the dependent variable, Total Innovation Investment, and x_{it} is a $(K + 1) \times 1 = X$ with the public procurement variables, as well as controls and $t - 1$ dummy variables. Where β can be consistently estimated using Driscoll-Kraay standard errors, explained below.

As demonstrated by Hoechle (2007), the respective fixed effects estimator is implemented in two steps. Firstly, all variables are within-transformed as follows: For $z_{it} \in \{y_{it}, x_{it}\}$,

$$\tilde{z}_{it} = z_{it} - \bar{z}_i + \bar{\bar{z}} \quad \text{where } \bar{z}_i = T_i^{-1} \sum_{t=t_{i1}}^{T_i} z_{it} \quad \text{and} \quad \bar{\bar{z}} = \left(\sum T_i \right)^{-1} \sum_i \sum_t z_{it}$$

Equation 1: Within-Transformation of All Variables

The within-estimator corresponds to the following simple Ordinary Least Squares (OLS) of

$$\tilde{y}_{it} = \tilde{x}'_{it}\beta + \tilde{v}_{it}.$$

In a second step, the transformed regression model is then estimated by pooled OLS estimation with Driscoll and Kraay standard errors for the coefficient estimates. To do so, the square roots are taken of the diagonal elements in the asymptotically robust covariance matrix below:

$$V(\hat{\beta}) = (X'X)^{-1} \hat{S}_T (X'X)^{-1}$$

Equation 2: Variance Estimation

Where Newey and West (1987) define \hat{S}_T as follows.

$$\hat{S}_T = \hat{\Omega}_0 + \sum_{j=1}^{m(T)} \omega(j, m) [\hat{\Omega}_j + \hat{\Omega}'_j]$$

Equation 3: Definition of \hat{S}_T -hat as proposed by Newey and West (1987)

This, with the modified Bartlett weights, positive semi-definiteness of \hat{S}_T is ensured as well as smoothing the autocovariance function in a way where higher order lags receive lower weights. Moreover, the lag length up to where the residuals may be autocorrelated is done, if not specified, using the plug-in procedure proposed by Newey and West (1994):

$$\omega(j, m(T)) = 1 - \frac{j}{m(T) + 1},$$

Equation 4: Bartlett Weights

$$m(T) = \text{floor} \left[4 \times \left(\frac{T}{100} \right)^{2/9} \right]$$

Equation 5: Plug-In Procedure for Lag Length as proposed by Newey and West (1994)

The matrix of $\hat{\Omega}_j$ is defined as below

$$\hat{\Omega} = \sum_{t=j+1}^T h_t(\hat{\beta})h_{t-j}, \quad \text{with } h_t(\hat{\beta}) = \sum_{i=1}^{N(t)} h_{it}(\hat{\beta})$$

Equation 6: Ω_j -hat Matrix

and orthogonality conditions are the $(K + 1) \times 1$ dimensional moment condition of the regression $h_{it}(\hat{\beta}) = x_{it}\hat{v}_{it}$

4.1.3. Testing for Time-Fixed Effects

To test whether to add time-fixed effects, a joint hypothesis test was done to see if all year dummies are equal to zero. This was rejected at a 1% significance level as can be seen in the appendix. Thus, time fixed effects were added to the model as dummies for each year except for 2009 to avoid multicollinearity.

5. RESULTS AND DISCUSSION

The final model is thus a fixed effects model with entity as well as year fixed effects using Driscoll-Kraay standard errors to account for cross-municipality dependence. Below is a comparison of all models explored, with control variables as well as year dummies hidden for ease in readability. The full final model can be seen in the appendix.

	FE (DK SE)	FE	RE	OLS
lngoods	0.220 (0.253)	0.220 (0.525)	0.257 (0.498)	0.220 (0.525)
lngoods2	-0.000945 (0.00806)	-0.000945 (0.00915)	0.00239 (0.00894)	-0.000945 (0.00915)
lnservices	-1.311* (0.582)	-1.311 (0.679)	-1.125* (0.538)	-1.311 (0.679)
lnservices2	0.00224 (0.0149)	0.00224 (0.0154)	0.0119 (0.0136)	0.00224 (0.0154)
lnworks	-0.808* (0.293)	-0.808* (0.352)	-0.954** (0.341)	-0.808* (0.352)
lnworks2	0.0127* (0.00460)	0.0127* (0.00643)	0.0165** (0.00633)	0.0127* (0.00643)
lngoodsCon~s	0.334 (0.509)	0.334 (0.481)	0.368 (0.463)	0.334 (0.481)
lngoodsCon~2	-0.0670 (0.0836)	-0.0670 (0.0832)	-0.0850 (0.0800)	-0.0670 (0.0832)
lnservices~s	0.212 (0.418)	0.212 (0.585)	0.212 (0.549)	0.212 (0.585)
lnservic~ts2	-0.0345 (0.0545)	-0.0345 (0.0849)	-0.0428 (0.0794)	-0.0345 (0.0849)
lnworksCon~s	-0.695 (0.501)	-0.695 (0.366)	-0.515 (0.350)	-0.695 (0.366)
lnworksCon~2	0.0968 (0.0983)	0.0968 (0.0620)	0.0499 (0.0586)	0.0968 (0.0620)
lngoodsxPo~n	-0.0290 (0.0275)	-0.0290 (0.0615)	-0.0383 (0.0584)	-0.0290 (0.0615)
lnservices~n	0.139 (0.0926)	0.139 (0.0904)	0.101 (0.0682)	0.139 (0.0904)
lnworksxPo~n	0.0789* (0.0315)	0.0789 (0.0410)	0.0889* (0.0399)	0.0789 (0.0410)
N	3892	3892	3892	3892
Within R2	0.104	0.104	0.0989	

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 1: Model Comparison with, from the right to the left, fixed effects using Driscoll-Kraay standard errors, fixed effects, random effects and pooled OLS.

The model shows a within R-squared of 10,4% meaning that the variation in our innovation output is moderately captured by the model. In other words, the procurement

activity accounts for roughly 10% of changes in innovation output within each municipality over time.

It is rapidly observable that neither public spending on goods nor the related number of contracts issued is statistically significant at a 10% significance level in our final model. However, the variables that show the most interesting results related to innovation output are public procurement in works and services. First, although the number of contracts is shown to be insignificant, the model proposed that a 1% change in service-related public procurement is associated with a 1.31% decrease in innovation output. Since the quadratic term of services is not significant, there are no marginal effects. Therefore, there is a negative elasticity of -1.31 of innovation-output with respect to public procurement of services. Nevertheless, it is important to note that some municipalities did not have an innovative output for each year and that, therefore, this negative number must be read with caution. Spending money on public procurement in services might not lower the innovative output of a municipality and should thus be avoided. In contrary, municipalities who spend a lot of money in public procurement of services might simply have been associated with more years of zero or low innovation output. Secondly, the effects of work-related contracts on innovation are more complex as shown in equation 7 below.

$$\ln(\text{innovation})_{it} = -0.808 \ln(\text{works})_{it} + 0.0127(\ln(\text{works})_{it})^2 + 0.0789 \ln(\text{works})_{it} \ln(\text{Population})_{it}$$

Equation 7: Effect of Public Procurement in Works on Innovation

The log-log model proposes that the effects of public procurement in works is negative, however, with positive marginal effects and positively dependent on the population of the municipality. Therefore, the effect public spending in works has on innovation output depends on the monetary volume and its population. It further shows that municipalities that grow fast can thus increase their work-related spending by lesser amounts than municipalities that grow at a slower rate.

Although this thesis takes a great step in understanding how public procurement can influence innovation at a regional level, the model also proposes some limitations. Although the fixed effects model allows controlling for omitted time-invariant variables, it might be exactly those variables that could help explain how and why certain municipalities can reap more benefits from public procurement. It might be that some municipalities communicate more efficiently, have a different working culture, are better managed or even have different innovation-targets than others, which could lead to them being more innovative or not.

6. CONCLUSIONS AND FUTURE WORKS

Public procurement can be a powerful tool in shaping a nation, regions and therefore people's lives. It should thus be studied very carefully in order to be used as efficiently as possible given a government's regional needs. There appears to yet a lot to discover on how public procurement of innovation works and what its advantages are. This thesis aims to take a step closer in explaining how public procurement can affect innovation output so that public spending can be used more strategically if a government is aiming to increase its innovation. It also aims to help policymakers reduce disparities amongst Portuguese regions in a way that allows municipalities to reap the benefits public procurement can have in a more targeted, studied and, therefore, efficient way.

In this thesis, to test the relation between public procurement and innovation, a fixed-effects model with Driscoll-Kraay standard errors was used to account for the dependence amongst municipalities. The final model proposes that the elasticity of innovation output with respect to public spending on services is of -1.31. Thus, a 1% change in service-related public spending is associated with a 1.3% decrease in innovation output. Nevertheless, given the nature of the dataset, there might have been a higher number of municipalities with zero or low-innovation output that might influence these findings. The model further proposes a more complex interpretation of the innovative effects public procurement in works can have. Not only are positive marginal effects observed, but the interaction term between work-related spending and population was also positive. This suggests that faster growing municipalities can spend less on public procurement in works to get the same innovative output as slow-growing municipalities.

Since the scope of this thesis could not cover all aspects of public procurement of innovation in Portugal, future studies can build on this in a myriad of ways. For example, by exploring the limitation of the fixed effect model and analyzing why different regions, namely the coastal North, behave the way they do and how other municipalities can incorporate these traits to increase their innovation output as well. A second branch of study can be done by exploring the effects the new institutionalization of the European law has on public procurement of innovation, as mentioned in the literature review. Furthermore, future studies can build on this thesis by adding the nature of innovations to further understand what sort of innovation public procurement can be best used for. Moreover, future works may include testing these findings for different types of innovation, for example, if innovation output is the same for SME and large corporations. The more research there is done in the field, the closer we get not only to using public procurement in the most efficient way but also to foster regional innovation output in a precise manner. This thesis takes a step forward by providing such information for Portugal.

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APPENDIX

Augmented Dickey Fuller Tests

Augmented Dickey-Fuller Test

data: FinalEN1\$TotalInvestment
Dickey-Fuller = -13.524, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

Augmented Dickey-Fuller Test

data: FinalEN1\$goods
Dickey-Fuller = -10.979, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

Augmented Dickey-Fuller Test

data: FinalEN1\$works
Dickey-Fuller = -11.897, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

Augmented Dickey-Fuller Test

data: FinalEN1\$services
Dickey-Fuller = -11.241, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

Augmented Dickey-Fuller Test

data: FinalEN1\$goodsContracts
Dickey-Fuller = -10.652, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

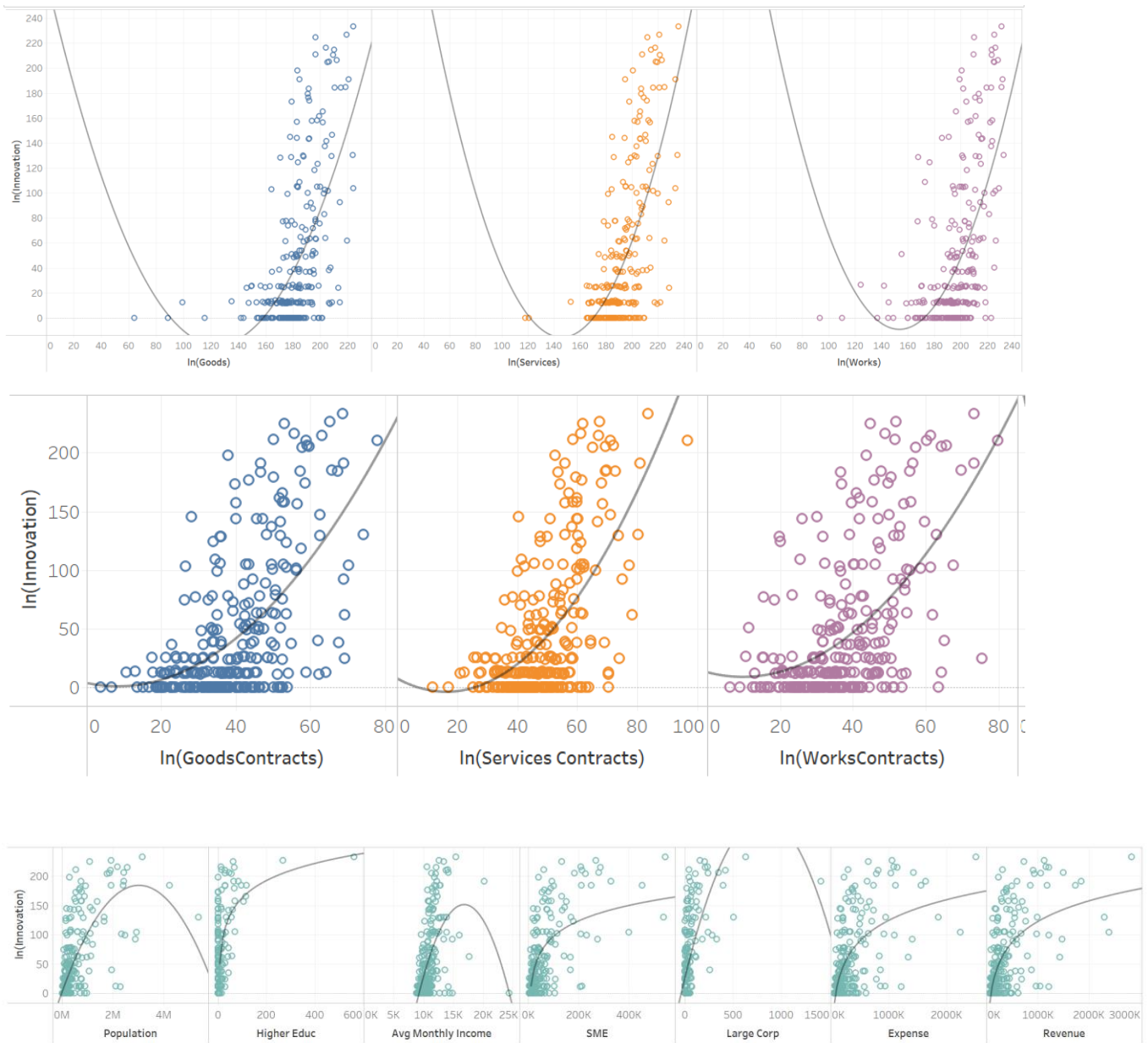
Augmented Dickey-Fuller Test

data: FinalEN1\$servicesContracts
Dickey-Fuller = -10.238, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

Augmented Dickey-Fuller Test

data: FinalEN1\$worksContracts
Dickey-Fuller = -10.477, Lag order = 15, p-value = 0.01
alternative hypothesis: stationary

Exploration of Linearity for Independent Variables



Hausman Specification Test: Random Effects or Fixed Effects

Test: Ho: difference in coefficients not systematic

$$\text{chi2(25)} = (b-B)' [(V_b - V_B)^{-1}] (b-B)$$

$$= 61.22$$

$$\text{Prob} > \text{chi2} = 0.0001$$

($V_b - V_B$ is not positive definite)

Pesaran's Cross-Sectional Dependence Test

Pesaran's test of cross sectional independence = **39.235**, Pr = **0.0000**

Average absolute value of the off-diagonal elements = **0.345**

Joint-Hypothesis Test for Time-Fixed Effects

```
. testparm i.year1
```

```
( 1) 2010.year1 = 0
( 2) 2011.year1 = 0
( 3) 2012.year1 = 0
( 4) 2013.year1 = 0
( 5) 2014.year1 = 0
( 6) 2015.year1 = 0
( 7) 2016.year1 = 0
( 8) 2017.year1 = 0
( 9) 2018.year1 = 0
(10) 2019.year1 = 0
(11) 2020.year1 = 0
(12) 2021.year1 = 0
(13) 2022.year1 = 0
```

```
F( 13, 13) = 3.5e+05
Prob > F = 0.0000
```

