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Corruption, the Shadow Economy and Innovation in Spanish Regions

Summary: The aim of this paper is to analyze the effects of corruption and the shadow economy on innovation in the Spanish regions between 2000 and 2012. For this purpose, we use different proxies to approximate corruption and the shadow economy. We find evidence that corruption negatively influences innovation according to the results of the estimations. Regarding the effect of the shadow economy on innovation, the results also suggest that tax fraud, which is directly related to underground activities, leads to a decrease in regional innovation.

Key words: Innovation, Corruption, Shadow economy, Spanish regions.

JEL: D73, O17, O32, R11.

"One of the keys to attract technology companies, startups and emerging companies to Spain is to end corruption." This was said by Kenneth Morse, Director of the Center for Entrepreneurship at the Massachusetts Institute of Technology (MIT), who states that one of the keys to fostering innovation and attracting technology companies to Spain is to eliminate corruption. Corruption is a great concern for most countries because it influences economic growth (Giorgio D'Agostino, J. Paul Dunne, and Luca Pieroni 2016). This phenomenon causes a lack of confidence in institutions; therefore, corruption does not act as a factor that promotes economic development (Andrés Rodríguez-Pose 2013).

The shadow economy includes not only legal but also economic consequences that have significant effects on the economic and monetary policies of a country (Friedrich Schneider and Dominik H. Enste 2000; Roberto Dell'Anno, Miguel Gómez-Antonio, and Ángel Pardo 2007). A large shadow economy may cause a country's leaders to make decisions based on indicators that are unrealistic with budgetary implications and influences on the taxation and distributive policy in that country (David E. A. Giles 1997).

Therefore, it is essential to reduce the levels of corruption and other associated phenomena, such as the underground economy, to encourage foreign capital coming onshore, increase investment and eventually promote innovation. Following this argument, the objective of this research is to test the negative impact of those phenomena on innovation in Spanish regions during the period between 2000 and 2012. Using panel data methodology, the results indicate that higher corruption or shadow economy levels lead to a decrease in the innovation success in the Spanish regions. These findings suggest that policymakers should pay more attention to these phenomena to improve the effectiveness of regional innovation.

The remainder of the paper is organized as follows. Section 1 presents the theoretical framework and the hypotheses. Section 2 describes the data and methodology. Section 3 includes the results. Finally, Section 4 contains the conclusions of the paper.

1. Theory and Hypotheses

The aim of this paper is to analyze the effects of corruption and the shadow economy on innovation in the Spanish regions. This is an issue that has not been treated frequently in the literature, and therefore, it is quite innovative. In this section, a literature review is presented to better understand these phenomena (shadow economy and corruption) and address the relationship between them and innovation based on the scant existing research on this issue.

1.1 Corruption and Innovation

According to the World Bank, corruption is the act of abuse of public office for private gain. Transparency International, which produces one of the most commonly utilized indices to approximate corruption, defines it as the abuse of entrusted power for private gain. This phenomenon arises as a special situation of the principal-agent relationship arising from agency theory (Alfredo Del Monte and Erasmo Papagni 2007). In this case, the principal is atypical because it is the state on behalf of citizens who with their votes elect representatives and public authorities. The agent is the public official in charge of managing the economic and financial decisions of the country. In this relationship, there are clear information asymmetries that the agent can employ to obtain an advantage, in which case it incurs an act of corruption. Following this line, Daron Acemoglu and Thierry Verdier (2000) argue that sometimes it is not efficient to establish control measures between the principal and the agent to prevent corruption because control costs may outweigh the benefits. These same authors also note that it is necessary to distinguish between corruption in public agencies and at the private level, although generally more attention has been paid to it in the public sphere. For the purposes of our work, we focus on the latter, which is the type of corruption that is commonly analyzed.

Therefore, the present paper attempts to fill some of these gaps in the literature by analyzing the relationship between corruption and innovation in the field of public finances. Although the channels through which corruption affects innovation are not clear in the literature, public institutions seem to be a key element in these transmission mechanisms. Considering classical approaches, in which institutions do not play a role in innovation, other approaches, such as the Regional Systems of Innovation (RSI) developed by Philip Cooke, Mikel Gómez Uranga, and Goio Etxebarría (1997), Learning Regions (Kevin J. Morgan 1997) and the development of New Institutional Economics (NIE), indicate that institutions, particularly at the regional level, can be a key factor in fostering innovation (Rodríguez-Pose and Marco Di Cataldo 2015). RSI, for instance, suggest that stronger regional institutions promote innovation. However, this system must be based on trust and the reliability of regional institutions. The institutional regional conditions, its knowledge infrastructures and knowledge transfer systems provide stimuli for promoting innovation activities (David Doloreux and Saeed Parto 2005).

Thus, it seems clear that corruption is an obstacle to development and innovation, particularly in emerging countries (Chi Keung Lau et al. 2015). In developing regions, the improvement of institutional quality boosted innovation. Laura Barasa et al. (2017) analyze East African regions and find that high institutional quality, which is related to lower levels of corruption, allows companies to better allocate their resources. They argue that this regional environment affects the ability of firms to introduce new innovations. In an analysis that encompasses more countries, Saul Estrin, Julia Korosteleva, and Tomasz Marek Mickiewicz (2013) analyze the effects of corruption on entrepreneurship. They suggest that corruption is a constraint for entrepreneurs and reduces innovation because corruption acts as a tax for new businesses (Chandan Sharma and Arup Mitra 2015), similar to the results obtained in Ruta Aidis, Estrin, and Mickiewicz (2012). Also Daphne Athanasouli and Antoine Goujard (2015) analyze corruption and innovation in Central and Eastern Europe. They find out that corruption leads to the adoption of governance structures which hinder innovation. Similarly, Caroline Paunov (2016), in a multi-country analysis, obtains that corruption reduces innovation investment.

Therefore, corruption reduces investment originating from within the country and discourages foreign investment (Shang-Jin Wei 1999). In addition, these studies suggest, as do Sergey Anokhin and William S. Schulze (2009) that this is because corruption inhibits foreign direct investment and reduces the chances of entrepreneurship in the country. Moreover, innovation is limited by the lack of confidence by entrepreneurs in institutions because corruption delays and hinders the ability to obtain permits and licenses (Lau et al. 2015). That is why some studies, such as that by Anokhin and Schulze (2009), find evidence that countries with lower levels of corruption exhibit a larger number of patent applications.

On the other hand, there are also supporters of the greasing hypothesis (Nauro Campos, Ralitza Dimova, and Ahmad Saleh 2010) which suggests that corruption *greases* economic growth (Nathaniel Leff 1964). Leff (1964) states that corruption allows the private sector to avoid inefficient regulations increasing efficiency. In this line, Daniel Levy (2007), finds out that black market can be efficient enhancing economic growth in Georgia, the former soviet Republic.

However, the negative effects of corruption are particularly evident and clear at the enterprise level where corruption reduces business income and increases agency and investment costs (Paolo Mauro 1995; Simeon Djankov et al. 2002). Gang Xu and Go Yano (2016) find that anti-corruption measures implemented in China have led to an increase in the number of patents and R&D investment in Chinese companies. Also, Prashanth Mahagaonkar (2010) suggests that there is a body of literature that affirms that corruption affects growth by reducing investment. In this respect, Marcelo Veracierto (2008) also analyzes how corruption affects the rate of business innovation. However, the absence of data on corruption has hampered, in many cases, achieving results in this line. On the other side, Keith Blackburn and Gonzalo F. Forgues-Puccio (2009) suggest that corruption may not be so harmful for innovation if the corruption activities are coordinated. In that case, the innovation activities and economic growth are not so damaged. Nevertheless, most of the empirical evidence shows that the existence of high-quality institutions that guarantee market opportunities and patent protection, i.e., low corruption levels, has a positive impact (Paunov 2016), as they mitigate the uncertainty that surrounds innovation.

Therefore, government institutions affect innovation by determining the level of certainty and providing trust and the transmission of knowledge between innovators (Rodríguez-Pose and Di Cataldo 2015) and promoting internal and foreign investments. Even if public and economic authorities do not provide these conditions, the innovative process will be harmed. In this sense, corruption is an element that generates greater uncertainty and less trust and hinders the transmission of knowledge. A greater control of corruption through more quality institutions would create the optimal institutional context to boost entrepreneurship and innovation (Anokhin and Schulze 2009). Contrary to that, therefore, higher levels of corruption deter innovation activities and R&D investment (Rudolf Sivak, Anetta Caplanova, and John Hudson 2011).

Thus, institutions indirectly affect innovation, as they should create the appropriate context with an adequate degree of rule of law and the absence of corruption. Nevertheless, corruption is also directly related to public institutions, as it is externalized through public spending within a state's finances (Mauro 1998). The increase in public spending may generate higher levels of corruption if it is not directed toward productive investment. In this respect, Vito Tanzi and Hamid R. Davoodi (1997) indicate that corruption affects public spending in different ways. First, it increases spending on unproductive sectors, which are more prone to corruption activities. Second, it increases allocations for public wages and salaries, subtracting those resources for other possible targets. This implies a higher level of general expenses for the state, and as noted by some studies (Robert J. Barro 1996; Simon Commander, Hamid R. Davoodi, and Une J. Lee 1997), this means less growth. It also causes a deterioration of the infrastructure. This generates increased costs in operations among economic agents, reducing the productive capacity of a country. Finally, it reduces the volume of state revenues, which limits countries' ability to grow and invest. It is for this reason that corruption would affect innovation in two ways: first, by shifting spending on innovation to other areas more susceptible to promoting activities of corruption and second, by reducing revenues and thus, resources for innovation (Mauro 1998).

At the regional level, Rodríguez-Pose and Di Cataldo (2015) state that innovative performance is directly conditioned by regional institutions. According to these authors, high-quality institutions, i.e., institutions with low levels of corruption play a key role in the innovative potential of European regions. They find evidence that corruption is a main determinant of innovation effectiveness in European regions and conclude that the efforts to reduce corruption can be as effective in improving innovation as increasing the expenditure in R&D. In this sense, Acemoglu and Melissa Dell

(2010) suggest that differences in productivity within countries are greater than between countries. They conclude that at a regional or local level, institutions are a key element to determine the technological process. Thereby, the regional analysis of the relationship between innovation and corruption is meaningful, and it is the main objective of this paper in the context of Spanish regions.

All these constraints arising from corruption limit innovation at the regional level because the innovation process is altered by the lack of confidence and trust in institutions. Moreover, from an economic point of view, corruption affects innovation in two ways: by shifting spending on innovation to other areas more susceptible to promoting activities of corruption and second, by reducing revenues and thus, resources for innovation. From these arguments, the following hypothesis is proposed:

Hypothesis 1: An increase in the level of corruption reduces the innovation of Spanish Autonomous Communities.

It is expected that there exists an inverse relationship between the two variables, so if corruption increases, the innovative capacity in Spanish regions is reduced.

1.2 Shadow Economy and Innovation

The analysis of the underground economy has been investigated by researchers and academics in recent decades and continues to be investigated. Evidence of this is the many works that have focused on quantifying the volume of the shadow economies in various countries and regions (Schneider 1994, 2008; Giles 1999; Schneider and Faith Savasan 2007; Helmut Herwartz, Egle Tafenau, and Schneider 2013). This matter has been the subject of increasing interest because of the implications of the underground economy to the finances of a country or region. An appropriate approximation of the underground economy allows authorities to enact appropriate economic policies that may be distorted if an adequate estimate of the shadow economy is not performed. Similarly, the causes and consequences of the underground economy, usually from a theoretical point of view, have been discussed, but for the interested reader it is recommendable to read the work of Schneider and Enste (2000) for a more detailed analysis of the causes and consequences of the underground economy, as well as other theoretical implications. In our case, the objective is to analyze the impact of the underground economy on innovation for the Spanish regions.

Even if the number of studies that analyze the influence of corruption on innovation is scarce, those on the relationship between the shadow economy and innovation are even fewer. The channels through which shadow economy affects the innovative process are not clear. Nevertheless, it is stated in the literature that the shadow economy influences public finances of a country or region (Ahmet Burçin Yereli, Ibrahim Erdem Seçilmiş, and Alparslan Basaran 2007). This can be observed both on the side of expenditure and that of revenue (María Arrazola et al. 2011). Thus, the shadow economy negatively affects public finances of a country in two ways: reducing revenues and increasing costs unnecessarily.

On the one hand, to the extent that the underground economy is focused primarily on avoiding paying taxes, the greater is the informal sector of the economy, the greater are the amounts evaded. Because taxes represent the main source of funding for a state, the fact that the shadow economy negatively influences their collection generates a reduction of public revenues. On the other hand, the underground economy also influences the side of public spending. In a territory where the underground economy levels are high, it distorts the economic indicators that are taken as reference for economic and financial policy decisions (Schneider and Enste 2000). Thus, expansionary policies could be adopted that would not be necessary because the indicators based on which they are adopted are biased downward (GDP) or upward (unemployment) due to the impact of the underground economy. In addition, an increase in the volume of the shadow economy generates more social transfers (Yereli, Seçilmiş, and Basaran 2007), increasing the level of spending in those sectors. This problem of unreliability has a significant territorial component (Francisco Javier Ferraro et al. 2002). For instance, those regions with a higher shadow economy could enjoy a more beneficial resource redistribution policy because they show some undervalued (GDP) or overvalued (unemployment, inflation) magnitudes.

Thus, the shadow economy diverts resource allocation toward apparently unproductive sectors or regions. This leads to investment decisions that are biased through underground activities that are in commonly medium- or low-innovative sectors such as construction, trade or services (Yair Eilat and Clifford Zinnes 2002).

All the above may pose problems of efficiency in the economy of a country distorting prices by altering the allocation of resources and the provision of public services (Arrazola et al. 2011) and reducing the incentives for companies to invest in long-term innovation projects. These problems cause an inappropriate allocation of public resources. On the one hand, they reduce government revenue, and on the other, costs artificially increase in areas where such an increase would not be necessary. Therefore, at the public level, the shadow economy affects innovation because primarily, the State has fewer resources to invest, and second, the resources available are assigned to areas of expenditure that are considered artificial priorities, and not to productive areas. It is worth noting that some authors suggest that the underground economy has also positive implications for the regular economy (Schneider and Enste 2000). They state that the underground economy can generate a competition with official economy fostering economic development. Moreover, part of the income generated in the underground economy is spent in the regular markets, increasing official activity and growth.

At the corporate level, there is evidence that corruption negatively affects innovation. Vito Amendolagine, Rosa Capolupo, and Giovanni Ferri (2014) find evidence in Italian regions that firms are more innovative where the underground economy is smaller. This is because in a context of high levels of the black economy, there is less incentive for the formal sector to engage in innovation (Organisation for Economic Co-operation and Development 2009; Dan Andrews, Aida Caldera Sánchez, and Asa Johansson 2011). Thus, in those regions with higher levels of the shadow economy, there is less incentive for the companies to innovate and invest in new products. Moreover, a large informal sector increases the risk of doing business and raises the effort to obtain funds in financial markets, leading the private sector to focus on the short-term (Aleksander Kaliberda and Daniel Kaufmann 1996). This has risky consequences for innovation activities that are generally focused on the long-term. Therefore, companies surrounded by high shadow economy levels tend to operate more laborintensively (Eilat and Zinnes 2002) and thus reduce their investment in research and innovation projects.

All this causes the total amount of resources to be reduced and the available resources to be directed toward specific sectors incorrectly because they do not really require that expense and reduce the incentives to innovate by the companies. That is why the following hypothesis is proposed:

Hypothesis 2: Those regions with higher levels of underground economy are more prone to reduced innovation because there are less public resources that invest in it and because formal firms have fewer incentives to engage in innovation.

It is expected, therefore, that there is an inverse relationship between the levels of the shadow economy and innovation.

2. Variables, Data and Methods

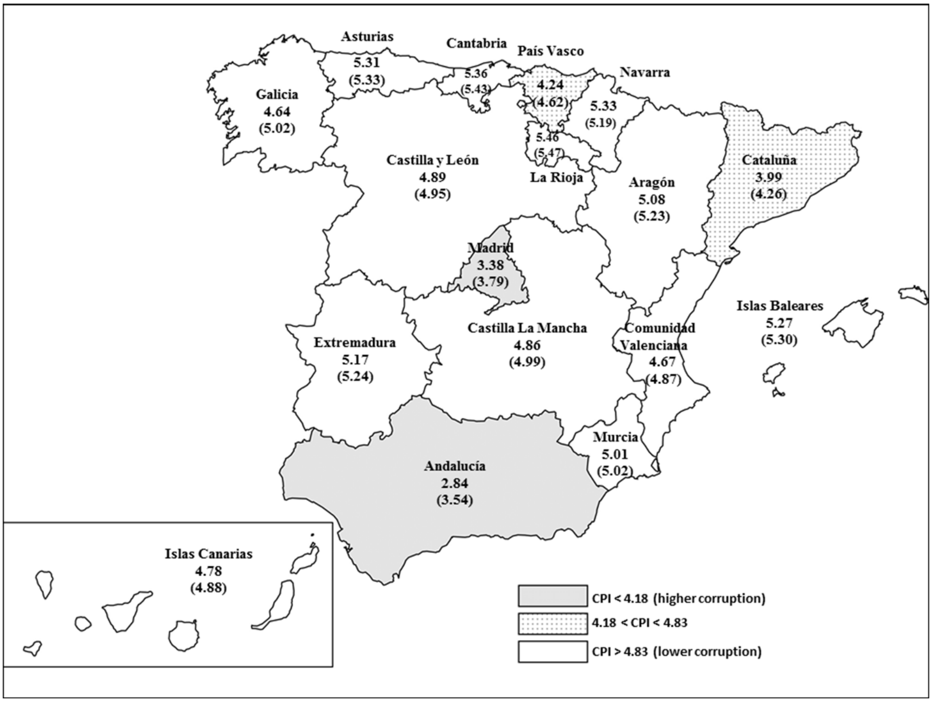
This section describes the data and methodology used in the empirical analysis to study the impact of the shadow economy and corruption on innovation in the Spanish regions between 2000 and 2012.

2.1 Variables and Data

Next, a description of the variables included in the analysis is presented. We outline the main variables and the data sources, starting with the two main variables of interest: the Corruption Perception Index and the shadow economy.

Corruption Perception Index (hereinafter CPI). We use it as an indicator of institutional quality or the perception of corruption, and we employ the index calculated for the Spanish regions in the study by Marcos González-Fernández and Carmen González-Velasco (2014). It is worth noting that CPI is a measure of perception of corruption similar to the Transparency International Index and other similar proxies which are commonly employed in the literature. This kind of indexes have the drawback that they proxy the perception of corruption, but not the corruption itself. The predicted values of this index in the Spanish regions are summarized in Figure 1 (see also Table A1 of the Appendix).

We can observe that Andalucía, Madrid, Cataluña and País Vasco are the Spanish regions with the highest corruption, and La Rioja and Navarra have the lowest corruption. Note that this index is interpreted inversely. That is, a higher index value indicates a higher level of transparency and lack of corruption. Therefore, given that the expected relationship with innovation is an inverse one, the expected sign for this variable is positive. We must also mention that CPI shows a low variability in the data, but this is consistent with other internationally accepted indexes, such as the Transparency International or Heritage Foundation indexes. To be thorough in the analysis, we also use the number of crimes against the Public Administration along with the number of crimes against the Justice Administration to approximate corruption (Del Monte and Papagni 2007) as a robustness measure of this item obtained from the National Statistics Office (hereinafter, NSO). The crimes against Public and Justice Administration include all crimes more likely to be related to corruption such as deception or perjury by public officials, abandonment and failure to prosecute crimes, bribery, influence peddling, concealment, obstruction of justice by public officials. This former measure attempts to be a more objective indicator since it represents a measure of the real corruption.



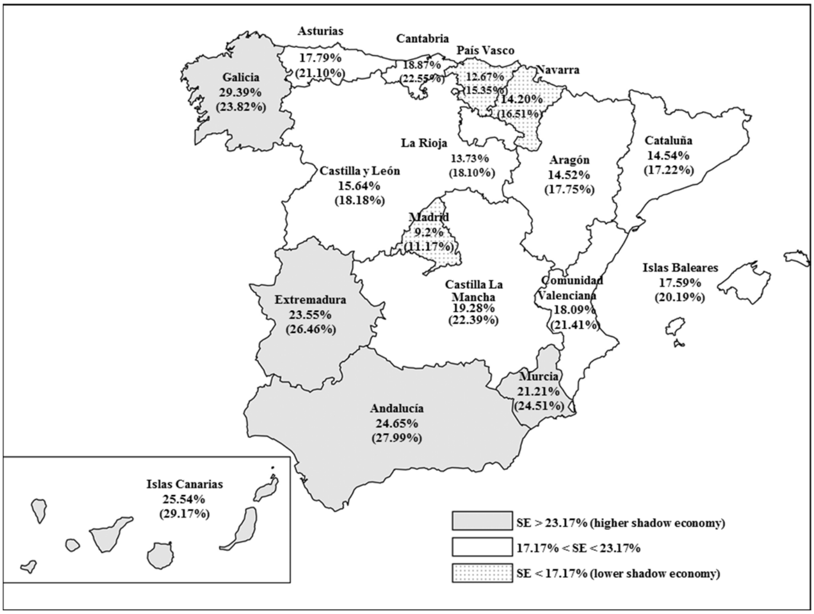
Notes: The map shows the values of the Corruption Perception Index (CPI) for the last year analyzed in each Spanish region. The value in brackets represents the average value for the CPI during the time horizon. The average CPI is between 3.54 and 5.47, and we distinguish three similar ranges related to three groups of regions: those with a CPI less than 4.18 (regions with higher corruption), those between 4.18 and 4.83 (regions with medium corruption), and those exceeding 4.83 (regions with lower corruption).

Source: Authors' calculations.

Figure 1 Corruption Perception Index by Spanish Region

Shadow economy. As a proxy of the underground economy, we employ the regional values of the informal sector related to the GDP calculated in the study from González-Fernández and González-Velasco (2015). These estimations have been obtained using the Currency Demand Approach, which is one of the most used procedures in the literature to estimate shadow economy levels.

This approach assumes that irregular activities use cash as payment, as it is less traceable. The authors apply this approach to the Spanish regions and obtain the estimations, which are summarized in Figure 2 (see also Table A2 of the Appendix). We can observe that Andalucía and Canarias are the Spanish regions with the highest shadow economy, and Madrid and País Vasco have the lowest shadow economy. As the shadow economy, for its own nature, is hard to measure, all estimations should be taken with caution. Therefore, another alternative variable, which is expected to be more objective, is included to approximate the level of underground economy. Namely, as these types of activities are commonly related to tax evasion and fiscal opacity, we include the number of crimes against tax authorities obtained from INE. The crimes against tax authorities include all crimes more likely to be related to the shadow economy such as tax fraud, subsidy fraud or accounting fraud.



Notes: The map shows the values of the shadow economy related to the GDP (SE) for the last year analyzed in each Spanish region. The value in brackets represents the average value for the shadow economy estimation during the time horizon. The average SE is between 11.17% and 29.17%, and we distinguish three similar ranges related to three groups of regions: those with an SE more than 23.17% (regions with a higher SE), those with an SE between 17.17% and 23.17% (regions with a medium SE), and those with an SE less than 17.17% (regions with a lower SE).

Source: Authors' calculations.

Figure 2 Shadow Economy by Spanish Region

The definitions and data sources of the rest of the variables are presented below.

Dependent variable

Patent growth. Patents have been used widely in the literature as proxies of innovative capacity. The final result of innovation is difficult to quantify. However, patents adequately reflect innovation (Zoltan J. Acs, Luc Anselin, and Attila Varga 2002) and are therefore frequently used in the literature to approximate the innovative effort (Mikel Buesa, Joost Heijs, and Thomas Baumert 2010; Victoria Kravtsova and Slavo Radosevic 2012; Eleanor Doyle and Fergal O'Connor 2013; Raffaello Bronzini and Paolo Piselli 2016). We use the annual growth of patents over the previous period in each of the Spanish regions. The data were obtained from Eurostat regional statistics

(European Commission 2016)[1]. The variable patents shows the patents applications to the European Patent Office (EPO), which are classified by region considering the region of residence of the inventor. These data are used instead of the data from the Spanish National Statistics Office (NSO) because there were changes in the methodology used for the NSO in the recompilation of these data during the period analyzed that could bias the results. We also use, as an alternative measure, the number of patents by the regional population (in millions) obtained from the same source.

Independent variables

Spending on Research and Development (hereinafter R&D) performed by the government. We do not include R&D staff in each of the Spanish regions because it is positively correlated to this variable and could cause multicollinearity problems in the estimations between the explanatory variables. We use the ratio of this variable relative to regional GDP. The data were obtained from Eurostat regional statistics (European Commission 2016). It is expected that the relationship with the dependent variable is positive. Because it is quite unlikely that the spending on R&D for a given year impacts the dependent variable in the same year, we use this variable lagged two periods. It is commonly accepted in the literature that there exists a lag between R&D investment and returns (Zvi Griliches 1979), which come from patents and tangible applications. Therefore, we assume that the resources that the government invests in R&D will pay off in two years. In the Appendix, Figure A1, we show a summary of the averages values for the data for R&D Investment and staff at R&D by Autonomous Communities to show the differences between Spanish regions. We can observe that regions like Cataluña and Comunidad de Madrid show the highest values for R&D, both regarding investing and R&D staff, whilst other regions such as La Rioja or Extremadura show the lowest values. These differences across regions are taken into account by including this variable.

Patents. The total number of patents registered in each region obtained from Eurostat regional statistics (European Commission 2016). We assume the existence of a direct relationship with the dependent variable.

Foreign direct investment (FDI). It is obtained as gross investment flows from abroad for each region relative to GDP. The data were obtained from the Ministry of Economy and Competitiveness, specifically from the DataInvex database (2016)[2], which is based on the Secretary of State for Commerce. Similar to the previous explanatory variables, we assume it is directly related to the growth in the number of patents.

Control variables for each of the Autonomous Communities

Unemployment. Higher unemployment causes a decrease in resources allocated to R&D and, thus, a reduction in institutional spending in this item. Therefore, it is

[1] **European Commission.** 2016. Database. https://ec.europa.eu/eurostat/web/regions/data/database (accessed September 17, 2016).

[2] **Ministry of Economy and Competitiveness.** 2016. DataInvex. http://datainvex.comercio.es/principal_invex.aspx (accessed September 17, 2016).

expected that the patent growth ratio is inversely related to this variable. The data were obtained from the Eurostat regional statistics (European Commission 2016).

Debt/GDP ratio. A higher level of debt causes regions to allocate resources and make cuts to reduce that figure. This results in fewer resources being available for R&D. Therefore, an inverse relationship with the dependent variable is assumed. The ratio is calculated as the ratio obtained by dividing the debt according to the Excessive Deficit Procedure (EDP) obtained from the Bank of Spain (2016)[3] and the regional GDP obtained from the Eurostat regional statistics (European Commission 2016).

Variables related to corruption and the shadow economy

Regarding the main objective of the paper, the following variables are included to analyze the effect of corruption and the shadow economy on innovation performance in the Spanish regions.

Table 1 presents the summary of the descriptive statistics for all the variables included in the analysis. We show the mean values for all those variables by regions.

Table 1 Summary Statistics of the Variables Included in the Analysis

Variable	Observed	Mean	Standard deviation	Minimum	Maximum
Growth in patents (%)	219	0.196	0.7964	-0.866	6.641
Expenditure R&D/GDP (-2) (%)	187	0.002	0.001	0.0008	0.0053
FDI/GDP (%)	221	0.009	0.019	0.000072	0.1671
Total patents (N)	220	71.28	111.51	0.67	524.93
Debt/GDP (%)	221	0.071	0.048	0.010	0.306
Unemployment (%)	221	0.127	0.638	0.041	0.344
CPI (index)	221	4.913	0.559	2.844	5.505
CPJA (N)	221	547.54	645.53	16	3700
SE (%)	187	0.208	0.050	0.088	0.322
CTA (N)	221	15.81	21.09	0	144

Notes: The table shows the summary statistics for the variables included in the analysis. The table displays the number of observations as well as the mean, standard deviation, and minimum and maximum descriptive statistics. We show the values of the public expenditures on R&D relative to GDP, foreign direct investment (FDI) relative to GDP, the total number of patents, the debt/GDP ratio, unemployment, CPI growth in the Spanish regions, the number of crimes against the Public and Justice Administration (CPJA), the shadow economy relative to GDP (SE) for the Spanish regions and the number of crimes against the tax authorities (CTA).

Source: Authors' calculations.

The descriptive statistics for the CPI show a mean value of 4.9, lower than the score for Spain, which is approximately 7. This is because the perception of corruption is higher at the regional level (Rémy Prud'Homme 1995). This result can be explained because of the greater number of relationships and interactions between public officials and private agents in federal or decentralized states, which provide increased opportunities for corrupt behavior. This hypothesis is confirmed by Daniel Treisman (2000), whose results indicate that federal states score from a half to a full point lower in the indexes of corruption than centralized countries.

[3] **Bank of Spain.** 2016. Statistics. https://www.bde.es/bde/en/areas/estadis/ (accessed September 17, 2016).

The regional analysis of the main variables included in the study (see Table A3 of the Appendix) indicates that the region with the lowest values for the CPI and, therefore, with the highest perceived corruption, is Andalucía, while the region with the least perceived corruption is La Rioja. We also include the mean values of the number of crimes against Public and Justice Administration. It seems that in those regions with a larger number of crimes of this nature (Andalucía, Madrid, Comunidad Valenciana or Cataluña), the CPI shows low values, which represent higher values of corruption. Namely, the correlation between those two variables is almost 80%.

Regarding the shadow economy, the mean value for all the regions is higher than 20%. It indicates that there exists a huge problem in Spain with regard to the underground economy. A fifth part of the GDP is currently trading in the shadows. For regions, the statistics show that Islas Canarias and Andalucía present higher levels of the shadow economy. On the other side, Madrid and the Foral Autonomous Communities (Navarra and País Vasco) present the lowest ratios for the underground economy. In this case, the number of crimes against tax authorities (CTA) does not show a high correlation with the shadow economy estimations (see Table A3 of the Appendix for more details).

2.2 Methods

To test the hypotheses and to analyze the determinants of innovation, we check whether the panel data methodology (Manuel Arellano 2003; Hans Jurgen Andreb, Katrin Golsch, and Alexander W. Schmidt 2013) is more appropriate than the Pooled OLS model. This latter technique analyzes a dataset as a panel through ordinary least squares regression. Therefore, it does not consider the unobservable heterogeneity of the sample.

Another key aspect of the panel data methodology, once its application has been justified against the pooled OLS model, is the choice between the fixed effects model and the random effects model in the estimation. According to William H. Greene (2003), the choice between the two methods depends on the unobserved variables that are not included in the model, which can be correlated with the variables introduced. If the equation does not include all possible explanatory variables, and the unobserved variables are correlated with the observed variables, the best choice is the fixed effects model; otherwise, the random effects model is more suitable (Kailan Cai, Richard Fairchild, and Yilmaz Guney 2008).

Once we have performed the appropriate tests to determine the suitability of the methodology of panel data in any of its modalities, the model is estimated to analyze the relationship among corruption, the shadow economy and innovation. Concretely, we propose the following model:

$$INNOV_{it} = \alpha_{it} + \beta X_{it} + CPI_{it} + \delta_i + \varepsilon_{it}; \quad (1)$$

$$INNOV_{it} = \alpha_{it} + \beta X_{it} + SE_{it} + \delta_i + \varepsilon_{it}, \quad (2)$$

where the subscripts i and t represent the Spanish regions included in the analysis and the time periods, respectively, where $i = 1, \ldots, 17$ and $t = 2000, \ldots, 2012$. In both equations, the dependent variable is a proxy to measure innovation, namely, the growth of patents over the previous period or the number of patents per millions of the regional population. The explanatory variables are grouped into X_{it}, which is a vector that includes the variables related to innovation, such as R&D expenditure of Public Administration lagged two periods relative to GDP, the number of patents, the foreign direct investment relative to GDP, and control variables such as unemployment and the debt/GDP ratio. In Equation (1), the variable CPI_{it} represents the CPI, which approximates the level of corruption, whereas in Equation (2), SE_{it} represents the variable related to the shadow economy. Finally, δ_i represents the region effect, and ε_{it} is the error term.

Furthermore, we consider the possible existence of autocorrelation and heteroskedasticity in the residuals of the models. To check for autocorrelation, we employ the test used by Jeffrey M. Wooldridge (2002), which states as the null hypothesis the absence of autocorrelation. Its rejection indicates that the dataset suffers autocorrelation, i.e., that there is a correlation between the error terms of each state throughout the time series (Stefan Eichler and Dominik Maltritz 2013). Regarding heteroskedasticity, we employ the modified Wald test (Christopher F. Baum 2001). In this case, the null hypothesis indicates that the error variance is constant, and its rejection indicates the presence of heteroskedasticity. In most macroeconomic datasets, the assumptions of no autocorrelation and homoscedasticity are not met, which may lead to bias in the significance of the estimates (Eichler and Maltritz 2013). To correct this problem, we employ robust standard errors clustered by countries (James H. Stock and Mark W. Watson 2008).

Correlation analysis

Table A4 of the Appendix summarizes the results of the correlations among the variables included in the analysis. The results show low correlations between the dependent and the explanatory variables. Nevertheless, the panel data methodology allows us to consider the unobservable heterogeneity among the studied regions that might arise from the expected relationship between the variables. We do not appreciate high correlations among the explanatory variables, which could lead to multicollinearity, with the exception of the correlation between patents (in logs) and the CPI. However, in the estimations, the multicollinearity diagnostics (Variance Inflation Factor) and tolerance indicate the absence of multicollinearity among the right-hand-side variables.

3. Analysis and Discussion of Results

This section reflects the results of the analysis of the effects of corruption and the shadow economy on innovation in the Spanish regions. It analyzes the effects of these phenomena, along with other variables related to innovation and control variables.

3.1 Influence of Corruption on Innovation

The analysis of the results regarding the effect of corruption on innovation is shown in Table 2. The estimates have been made employing different methodologies. The first two columns show the results the pooled OLS estimations. In the next columns, the analysis is performed utilizing the panel data techniques of random and fixed effects.

Time dummies are included to check the temporal persistence of the estimation in all the models.

In view of the results in Table 2, the variable that approximates the perception of corruption demonstrates a direct relationship with the dependent variables in models with the pooled OLS and random effects estimations. It should be noted that the interpretation of the CPI is inverse. That is, a higher CPI is indicative of reduced corruption. Therefore, the positive sign on this variable indicates that an increase in corruption reduces innovation, and therefore, the relationship between innovation and corruption is an inverse one. The same occurs for the number of crimes against the Public and Justice Administration. There exists an inverse relationship between this variable and the growth of patents in models 2 and 4.

Table 2 Panel Data Regressions of Corruption on Innovation

Dependent variable: annual growth in patents	**Model (1) OLS**	**Model (2) OLS**	**Model (3) Random effects**	**Model (4) Random effects**	**Model (5) Fixed effects**	**Model (6) Fixed effects**
Expenditure R&D/GDP (-2)	42.37	6.603	42.37	6.603	26.36	29.40
	(70.69)	(66.00)	(61.25)	(62.88)	(167.9)	(185.5)
FDI/GDP	-1.365	-1.818	-1.365	-1.818	0.392	0.560
	(3.390)	(3.564)	(2.714)	(3.060)	(1.942)	(1.976)
Total patents (in logs)	0.0390	0.176***	0.0390	0.176**	0.864***	0.866***
	(0.0643)	(0.0617)	(0.0353)	(0.0773)	(0.108)	(0.109)
Debt/GDP	-1.004	0.365	-1.004	0.365	2.365	2.000
	(1.082)	(1.038)	(0.996)	(0.784)	(1.885)	(2.206)
Unemployment	0.0139	0.0561***	0.0139	0.0561***	0.0291	0.0355
	(0.0149)	(0.0189)	(0.00918)	(0.0211)	(0.0366)	(0.0416)
CPI	0.197*		0.197*		-0.267	
	(0.105)		(0.102)		(0.229)	
CPJA (in logs)		-0.426***		-0.426**		-0.281
		(0.155)		(0.175)		(0.354)
Constant	-0.889	1.353**	-0.889	1.353**	-1.283	-1.305
	(0.964)	(0.652)	(0.835)	(0.559)	(0.980)	(1.730)
Time dummies	YES	YES	YES	YES	YES	YES
N	185	185	185	185	185	185
R^2	0.070	0.121	0.065	0.118	0.213	0.213

Notes: The table presents the panel data regressions of corruption and other explanatory variables on innovation, for which the growth in the number of patents serves as a proxy. As an explanatory variable, we include public expenditure on R&D relative to GDP as an indicator for R&D input. Because this variable is highly unlikely to provide patents in the same period, we consider the values of the variable lagged two periods. We also include as explanatory variables the foreign direct investment (FDI) relative to GDP, the total number of patents, the debt/GDP ratio and unemployment. To approximate the corruption, we employ the CPI in the Spanish regions calculated by González-Fernández and González-Velasco (2014) as well as the number of crimes against the Public and Justice Administration (CPJA). In the first model, we apply the pooled OLS model, and then, in columns 2-6, random and fixed effects models are applied. All models include time dummies. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

In the light of the results, there is a negative influence by corruption on innovation, but these results are not significant for the fixed effects estimation. Nevertheless, these results should be taken with care because there could be an endogeneity bias in the results as a causal relationship among some of the explicative variables and the left hand side variable is likely to exist. Therefore, a dynamic approach to solve this problem is required. For this purpose, a dynamic panel data technique is conducted through GMM (Arellano and Stephen Bond 1991; Arellano and Olympia Bover 1995). The results are shown in Table 3. In this table, we use as dependent variables the growth in patents, as in Table 2, but the left-hand side variable, the number of patents by the regional population (in millions), is also included as a robustness proxy. The values of the post-estimation coefficients (Z_1, Z_2, M_1, M_2 and Sargan test) are presented at the bottom of Table 3. Excluding the value for the Z_1 coefficient in the first model, they all show the expected significance, indicating the validity of the estimates.

Table 3 Dynamic Panel Data Regressions of Corruption on Innovation

Dependent variable	Growth patents (1)	Growth patents (2)	Patents by million (3)	Patents by million (4)
Expenditure R&D/GDP (-1)	477.5**	310.8	11,162**	6,906*
	(200.2)	(218.5)	(5,167)	(4,039)
Expenditure R&D/GDP (-2)	-380.5**	-232.3	-11,919*	-8,583
	(174.4)	(194.6)	(6,498)	(5,267)
FDI/GDP	-2.548	-1.527	-8.920	10.04
	(3.969)	(3.860)	(42.77)	(35.80)
Total patents (in logs)	-0.00313	0.187**	6.028***	11.85***
	(0.0712)	(0.0738)	(1.327)	(2.975)
Debt/GDP	-1.198	0.378	-69.34***	-29.21*
	(0.819)	(0.911)	(23.51)	(15.46)
Unemployment	0.00847	0.0624***	-0.0938	0.938**
	(0.0115)	(0.0199)	(0.247)	(0.429)
CPI	0.197		6.419***	
	(0.131)		(2.017)	
CPJA (in logs)		-0.498***		-13.83***
		(0.160)		(3.714)
Growth in patents (-1)	-0.246***	-0.240***		
	(0.0327)	(0.0261)		
Patents by million (-1)			0.710***	0.579***
			(0.0691)	(0.0685)
Constant	-1.068	0.908*	-26.78	47.23***
	(1.169)	(0.517)	(17.49)	(10.97)
Time dummies	YES	YES	YES	YES
Z_1	8.46 (5)	12.04 (5)**	24.03 (5)***	21.80 (5)***
Z_2	31.79 (10) ***	61.37 (10) ***	44.51 (10) ***	205.36 (10) ***
M_1	-1.91	-1.77	-1.99	-2.01
M_2	-1.10	-1.34	0.79	0.74
Sargan	208.97	221.67	128.14	130.09
N	179	179	180	180

Notes: The table presents the panel data regressions of corruption and other explanatory variables on innovation, for which the growth in the number of patents serves as a proxy (models 1 and 2) as well as the number of patents by the population (in millions) (models 3 and 4). As an explanatory variable, we include public expenditure on R&D relative to GDP as an indicator for R&D input. We also include as explanatory variables the foreign direct investment (FDI) relative to GDP, the total number of patents, the debt/GDP ratio and unemployment. To approximate the corruption, we employ the CPI in the Spanish regions calculated by González-Fernández and González-Velasco (2014) as well as the number of crimes against Public and Justice Administration (CPJA). We perform a Generalized Method of Moments or GMM analysis. Specifically, we employ the Arellano and Bond (1991) estimation using one lag for the dependent variable. We consider the public expenditure on R&D relative to GDP and the total number of patents as endogenous variables. The Z_1 is a contrast of joint specification of the explanatory variables; Z_2 is a contrast for the time dummies variables; M_1 is the serial correlation of first order; M_2 is the serial correlation of second order, and *Sargan* represents a Sargan test. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

The results reported in Tables 2 and 3 support hypothesis 1 (H_1), showing the existence of an inverse relationship between innovation and corruption in the Spanish regions. These results are robust regardless of the proxy used to approximate corruption, although the results of the number of crimes against Public and Justice Administration seem to be more stable than those for the CPI. These results are robust for the estimation method (OLS, random effects or GMM) employed, with the exception of the fixed effects estimation. Nevertheless, the dynamic panel data analysis leads to the results closest to those expected (Reza Najarzadeh, Farzad Rahimzadeh, and Michael Reed 2014), as it addresses the endogeneity bias that may arise from the data. Therefore, the results of the GMM seem to be the most reliable.

Regarding the rest of the variables in this dynamic model, there are some interesting results that deserve greater discussion. As shown in Table 3, the public expenditure on R&D has a significant positive impact on innovation but only the expenditure executed in the previous year. The public expenditure on R&D lagged two periods shows a negative sign in all the models, and it is significant in some of the specifications. In the non-dynamic approach (Table 2), the results do not even indicate a relationship between innovation and public expenditure on R&D. The absence of a robust positive relationship, which would be expected, between the expenditure by the public sector on R&D and innovation has drawn our attention even while it is not the main objective of the paper. This atypical result could find its explanation in the Regional Innovation Paradox (Christina Oughton, Mikel Landabaso, and Morgan 2002). The Regional Innovation Paradox is the greater need of lagging regions to invest in innovation and their relatively lower capacity to absorb funding compared to more advanced regions (Alessandro Muscio, Alasdair Reid, and Lorena Rivera León 2015). There are technological and development differences between regions that influence the effect that public funds have on innovation. As a result of this, lagging regions face more difficulties in utilizing public resources earmarked for innovation (Oughton, Landabaso, and Morgan 2002). Because our data include all Spanish regions, with different levels of development, this could explain the absence of significance or the negative sign for the public expenditure on R&D. This argument is in line with Acemoglu and Dell (2010) who suggest that at the regional level, there are greater productivity differences than between countries. In this sense, and to clarify this issue, a further analysis on this topic paying greater attention to the differences between regions and their starting point, referring to innovation and technological development, should be required.

Something similar occurs with the unemployment rate measure. According to the results from Tables 2 and 3, unemployment is directly related to innovation. This result is not significant for all the models, but it deserves discussion. The possible explanation for this is found in Joseph E. Stiglitz (2014). He considers that in a context of high labor costs, firms tend to replace labor by innovation, leading to a higher level of unemployment. Therefore, there is a tradeoff between unemployment and innovation, which explains the direct relationship between these variables.

3.2 Influence of the Shadow Economy on Innovation

Table 4 presents the results obtained for the analysis of the effect of the shadow economy on innovation. As in the previous subsection, we apply different estimation methods and include time dummies in all the models. The explanatory variables are those previously mentioned, and to approximate the shadow economy, we utilize the estimates obtained by González-Fernández and González-Velasco (2015) and the number of crimes against tax authorities (CTA).

Table 4 Panel Data Regressions of the Shadow Economy on Innovation

Dependent variable: annual growth in patents	Model (1) OLS	Model (2) OLS	Model (3) Random effects	Model (4) Random effects	Model (5) Fixed effects	Model (6) Fixed effects
Expenditure R&D/GDP (-2)	25.90	17.09	25.90	17.09	180.6	94.41
	(79.59)	(43.86)	(66.50)	(29.93)	(305.3)	(144.3)
FDI/GDP	-2.515	-0.670	-2.515	-0.670	0.186	0.285
	(4.099)	(2.376)	(3.264)	(1.593)	(2.256)	(1.043)
Total patents (in logs)	-0.0568	0.0565	-0.0568*	0.0565**	0.978***	0.786***
	(0.0750)	(0.0404)	(0.0319)	(0.0279)	(0.108)	(0.144)
Debt/GDP	-1.313	-0.0325	-1.313	-0.0325	0.215	3.104
	(1.118)	(0.932)	(0.981)	(0.704)	(2.628)	(1.786)
Unemployment	-0.000498	0.0143	-0.000498	0.0143***	0.0382	-0.00344
	(0.0172)	(0.00989)	(0.0114)	(0.00444)	(0.0408)	(0.0178)
SE	-0.611		-0.611		-7.613	
	(1.807)		(1.361)		(5.759)	
CTA (in logs)		-0.0715*		-0.0715***		-0.0363
		(0.0400)		(0.0223)		(0.0509)
Constant	0.414	-0.338	0.544	-0.0500	-2.395**	-2.935***
	(0.530)	(0.241)	(0.338)	(0.131)	(0.844)	(0.685)
Time dummies	YES	YES	YES	YES	YES	YES
N	151	167	151	167	151	167
R^2	0.055	0.082	0.027	0.089	0.210	0.362

Notes: The table presents the panel data regressions of corruption and other explanatory variables on innovation, for which the growth in the number of patents serves as a proxy. As an explanatory variable, we include public expenditure on R&D relative to GDP as an indicator for R&D input. Because this variable is highly unlikely to provide patents in the same period, we consider the values of the variable lagged two periods. We also include as explanatory variables the foreign direct investment (FDI) relative to GDP, the total number of patents, the debt/GDP ratio and unemployment. To approximate the shadow economy relative to GDP (SE), we employ the estimations for Spanish regions (SE) calculated by González-Fernández and González-Velasco (2015) as well as the number of crimes against tax authorities (CTA). In the first model, we apply the pooled OLS model, and then, in columns 3-6, random and fixed effects models are applied. All models include time dummies. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

Regarding values of the variable that approximates the underground economy, the results show the expected negative sign but only when the number of crimes against tax authorities is used as a proxy for the shadow economy and for the OLS and random effects estimation. The estimations for the shadow economy from González-Fernández and González-Velasco (2015) do not provide significant results in any of the models. Thus, the results of the shadow economy are not as robust as those for corruption, but there are traces of the negative influence of the shadow economy on innovation.

Table 5 Dynamic Panel Data Regressions of the Shadow Economy on Innovation

Dependent variable	Growth patents (1)	Growth patents (2)	Patents by million (3)	Patents by million (4)
Expenditure R&D/GDP (-1)	636.9***	485.4	12,889**	4,163
	(206.2)	(348.8)	(5,508)	(3,707)
Expenditure R&D/GDP (-2)	-541.2**	-419.9	-16,074**	-4,688
	(265.8)	(310.6)	(7,316)	(4,438)
FDI/GDP	-2.896	-0.982	-33.72	-25.78
	(5.935)	(2.360)	(57.19)	(55.08)
Total patents (in logs)	-0.142	0.0424	3.545***	5.487***
	(0.110)	(0.0280)	(1.296)	(1.464)
Debt/GDP	-0.564	-0.202	-63.60**	-45.55**
	(1.460)	(0.545)	(28.79)	(20.30)
Unemployment	-0.0116	0.0143***	-0.411	-0.426*
	(0.0132)	(0.00425)	(0.290)	(0.239)
SE	-1.024		-28.18	
	(2.063)		(26.46)	
CTA (in logs)		-0.0966***		-1.857***
		(0.0314)		(0.678)
Growth in patents (-1)	-0.285***	-0.249***		
	(0.0412)	(0.0420)		
Patents by million (-1)			0.806***	0.691***
			(0.0595)	(0.0699)
Constant	0.829*	-0.297		
	(0.481)	(0.204)		
Time dummies	YES	YES	YES	YES
Z_1	6.95 (5)	20.65 (5)***	13.24 (5)**	22.15 (5)***
Z_2	14.50 (8) *	60.75 (8) ***	25.88 (8) ***	86.67 (8) ***
M_1	-1.81	-2.89	-1.79	-1.94
M_2	-0.41	-1.70	0.11	1.50
Sargan	177.52	149.34	126.81	138.00
N	150	161	151	162

Notes: The table presents the panel data regressions of corruption and other explanatory variables on innovation, for which the growth in the number of patents serves as a proxy (models 1 and 2) as well as the number of patents by the population (in millions) (models 3 and 4). As an explanatory variable, we include public expenditure on R&D relative to GDP as an indicator for R&D input. We also include as explanatory variables the foreign direct investment (FDI) relative to GDP, the total number of patents, the debt/GDP ratio and unemployment. To approximate the shadow economy to relative to GDP (SE), we employ the estimations for Spanish regions (SE) calculated by González-Fernández and González-Velasco (2015) as well as the number of crimes against tax authorities (CTA). We perform a Generalized Method of Moments or GMM analysis.

Specifically, we employ the Arellano and Bond (1991) estimation using one lag for the dependent variable. We consider the public expenditure on R&D relative to GDP and the total number of patents as endogenous variables. The Z_1 is a contrast of joint specification of the explanatory variables; Z_2 is a contrast for the time dummies variables; M_1 is the serial correlation of first order; M_2 is the serial correlation of second order, and *Sargan* represents a Sargan test. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

As the endogeneity bias exists in this estimation as well, the dynamic approach through GMM estimation is presented in Table 5. As a dependent variable, we use the annual growth of patents in models 1-2 and the number of patents by the population (in millions) as a robustness measure in models 3-4. From the table, the negative influence of the shadow economy approximated by the number of crimes against tax authorities (CTA) is confirmed but not when the shadow economy estimations (SE) are included. These results confirm our H_2, which establishes a negative relationship between the shadow economy and innovation. Nevertheless, this finding is more sensitive to the proxy used for the shadow economy than for the case of corruption.

Regarding the remaining control variables, the results are similar to those obtained in Table 3. There is not a clear positive effect of public expenditure on R&D on innovation performance, and the unemployment shows a positive sign in models 2 and 4. As it was previously discussed, it can be a consequence of the Regional Innovation Paradox (Oughton, Landabaso, and Morgan 2002) and the tradeoff between innovation and workforce that leads to an increase in the unemployment rate (Stiglitz 2014).

In short, the analyses conducted allow obtaining evidence of the existence of an inverse relationship between corruption and innovation, which coincides with the expected results. This finding is robust to the measure of corruption used and for different proxies of innovation. Therefore, in this paper, we have found empirical evidence that institutional quality, or the absence of corruption, has a positive impact on innovation in Spanish regions. These results shed light on the scarce literature that relates corruption and innovation, especially in Spain. Our findings agree with previous works that state that the regional environment incentivizes the innovation process (Cooke, Stephen Roper, and Peter Wylie 2003; Doloreux and Parto 2005). Similarly, our results are in line with Rodríguez-Pose and Di Cataldo (2015), who state that corrupt institutions represent an important obstacle to innovative capacity in regions of the peripheral European countries and undermine any potential effect of measures aimed at promoting greater innovation.

The estimates also support this inverse relationship with the shadow economy, but only for the variable that acts as a proxy for the shadow economy through the number of crimes against tax authorities. This lack of robustness regarding the results for the shadow economy is not strange as, unlike corruption, there is a considerable amount of literature that affirms that the negative effect the black economy has on economic growth is unclear. In this sense, some authors suggest that the shadow economy maintains economic activity, since part of the money obtained in the informal sector is spent in the official sector (Eilat and Zinnes 2002). Thus, it increases the competition in the official sector, and according to Patrick K. Asea (1996), it allows the creation of new markets, increasing financial resources and enhancing entrepreneurship, which may help improve and boost the innovation process. This is in line with Schneider and Enste (2000), who argue that there may also be positive implications for the underground economy. In fact, they suggest that a growing shadow economy can compete with the official recorded activity. In addition, much of the rents generated in the shadow economy are spent in the regular economy, increasing official activity and production.

4. Conclusions

This paper analyzes the effects of corruption and the shadow economy on innovation in Spanish regions. This issue is of growing interest in Spain, particularly as it relates to corruption, and it is increasingly more attractive to economists and researchers given its impact on political, social, and economic issues.

In this sense, the article provides interesting findings in the study of this topic. First, different proxies to approximate corruption and the shadow economy are included. Along with the estimations for corruption and the shadow economy from previous works, we use objective measures that can approximate corruption and underground economy. Specifically, the numbers of crimes against Public and Justice Administration and against tax authorities are employed. In the empirical analysis, evidence of an inverse relationship between corruption and regional innovation is found. This result is robust to the measure used to approximate corruption and to the methodology employed. It implies that higher levels of corruption at the regional Spanish level hinder innovation. Notwithstanding that the analysis of this relationship is relatively new, there are some valuable studies in the literature that supports this results. The findings presented here contribute to generating a greater theoretical basis and greater discussion of the nature of this relationship.

According to these results, public authorities should implement measures not only to boost innovation directly but also to provide the institutional environment, absent from corruption, which do not harm the innovative process. In this sense, there are several measures policy makers should take into account. Regarding the public administration, there should be a strict control of public subsidies through independent control agencies to ensure that resources are used in productive sectors that promote innovation. Therefore, public authorities must track all the public funds allocated to promote R&D in order to disincentive corrupt behavior. In addition, policy makers have to ensure that this funding produces the expected results in terms of innovation.

This is especially important in the presence of the Regional Innovation Paradox. According to the estimations, there is not a persistent positive relationship between the regional R&D public expenditure and innovation as should be expected. This absence of a robust relationship between these two variables may be due to the different capacities of the Spanish regions to absorb public funds and transform them into tangible innovation items. This, which is called the Regional Innovation Paradox, occurs because less developed regions have more difficulties in converting these public funds in patents. Hence, lagging regions, which are usually those with higher levels of corruption, have more problems converting funding in innovation compared to other advanced regions. Thus, public authorities should focus their efforts on these regions in the first place in order to balance the capacity for innovation in all regions. Similarly, it is necessary to implement periodical supervision and control mechanisms by private agents who monitor the public administration. It is also necessary to create mechanisms that incentivize the reporting of cases of corruption, either by public officials or by companies. This would deter corruption and increase the certainty the private sector needs in order to carry out long-term investments in the innovation process.

Second, and regarding the underground economy, the analyses provide similar outcomes. In this case, only one of the proxies to approximate the shadow economy presents significant results, and therefore, the results are not as robust as for corruption. Nevertheless, these findings should also serve to make policymakers aware of the phenomenon of the black economy and its impact on economic activity. Despite that the pernicious effects of the underground economy on innovation are not as clear as for corruption, there are some measures policy makers should take into account to reduce the shadow economy and boost innovation. In particular, measures aimed at providing tax advantages for innovation activities and investments would boost innovation and reduce the shadow economy simultaneously, since taxes are one of the main causes of the informal sector.

Outside the core of the study, the results of the variable of the regional R&D public expenditure are striking. According to the estimations, there is not a persistent positive relationship between the regional R&D public expenditure and innovation as should be expected. This absence of a robust relationship between these two variables may be due to the different capacities of the Spanish regions to absorb public funds and transform them into tangible innovation items. This, which is called the Regional Innovation Paradox, occurs because less developed regions have more difficulties in converting these public funds in patents. This finding could be a starting point for analyzing this paradox in the Spanish context to a deeper extent in future research papers.

Ultimately, this work is a starting point for subsequent articles to analyze in greater detail the nature of the relationship between these two phenomena and innovation. Similarly, it is interesting to analyze the relationship between corruption and the shadow economy and other economic or financial factors.

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Appendix

Table A1 Corruption Perception Index by Spanish Region

Region\Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Andalucía	4.51	4.02	3.99	3.94	3.85	3.73	3.65	3.57	3.11	2.93	2.88	3.04	2.84
Aragón	5.24	5.24	5.27	5.24	5.22	5.25	5.28	5.32	5.39	5.18	5.12	5.11	5.08
Asturias	5.22	5.23	5.31	5.31	5.32	5.40	5.45	5.40	5.36	5.34	5.33	5.31	5.31
Illes Balears	5.35	5.36	5.34	5.33	5.33	5.30	5.30	5.40	5.25	5.24	5.21	5.24	5.27
Canarias	4.96	4.94	5.05	5.01	4.98	4.80	4.86	4.84	4.96	4.67	4.76	4.81	4.78
Cantabria	5.45	5.46	5.49	5.51	5.46	5.41	5.44	5.41	5.42	5.39	5.36	5.37	5.36
Castilla-León	4.97	4.87	4.91	4.98	5.05	5.02	5.03	4.98	4.94	4.90	4.93	4.85	4.89
Castilla-Mancha	5.24	5.13	5.13	5.09	5.13	5.09	4.96	5.00	4.90	4.87	4.77	4.73	4.86
Cataluña	4.99	5.23	5.02	5.28	4.22	4.38	4.16	4.00	3.66	3.28	3.48	3.71	3.99
C. Valenciana	4.93	4.64	4.71	5.19	4.84	4.95	5.09	5.30	5.10	4.65	4.68	4.53	4.67
Extremadura	5.25	5.25	5.30	5.27	5.25	5.32	5.27	5.25	5.24	5.22	5.15	5.19	5.17
Galicia	5.39	5.36	5.37	5.33	5.42	5.09	4.91	4.86	4.85	4.68	4.74	4.64	4.64
C. Madrid	4.00	4.15	4.14	3.94	3.93	3.88	3.85	3.78	3.70	3.44	3.55	3.52	3.38
Murcia	5.23	5.20	5.24	5.23	5.24	5.21	5.31	5.22	5.23	5.04	5.01	5.01	5.02
Navarra	5.27	5.25	5.43	5.41	5.38	5.10	5.16	5.05	5.06	4.99	5.03	5.04	5.33
País Vasco	5.45	5.42	4.78	4.72	5.16	4.51	4.49	4.36	4.27	4.19	4.32	4.21	4.24
Rioja	5.47	5.48	5.48	5.48	5.47	5.46	5.47	5.46	5.46	5.46	5.47	5.48	5.46
Average	5.11	5.07	5.06	5.07	5.01	4.94	4.92	4.89	4.82	4.68	4.69	4.69	4.72

Notes: The table shows the estimations for the corruption perception index (CPI) for each of the Spanish regions obtained from González-Fernández and González-Velasco (2014).

Source: González-Fernández and González-Velasco (2015).

Table A2 Shadow Economy by Spanish Region

Region\Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Andalucía	29.03	29.38	29.57	29.35	28.42	30.17	29.45	27.06	26.26	24.55	24.65
Aragón	19.16	18.59	19.23	18.40	18.36	19.74	18.75	17.30	16.30	14.86	14.52
Asturias	22.37	21.92	23.16	22.64	22.48	22.18	22.16	20.15	19.13	18.08	17.79
Illes Balears	21.45	21.57	22.08	21.39	20.55	21.06	20.83	19.06	18.72	17.80	17.59
Canarias	29.89	31.38	32.20	31.23	30.39	31.06	29.81	27.37	26.66	25.33	25.54
Cantabria	23.78	24.10	25.29	23.51	23.34	23.87	23.26	24.66	18.71	18.63	18.87
Castilla-León	19.35	18.57	18.95	18.62	18.69	19.88	19.81	17.98	16.78	15.73	15.64
Castilla-Mancha	23.39	23.65	23.63	23.63	23.25	23.93	23.54	21.60	20.98	19.36	19.28
Cataluña	18.72	19.22	19.14	18.51	18.00	18.06	17.42	16.11	15.26	14.46	14.54
C. Valenciana	23.93	24.95	25.04	23.55	22.25	22.07	21.06	18.67	18.16	17.69	18.09
Extremadura	25.95	27.25	27.61	27.38	27.49	29.04	28.62	25.84	24.77	23.59	23.55
Galicia	24.69	24.85	25.30	24.81	24.97	25.87	25.83	22.99	21.97	20.30	20.39
C. Madrid	12.92	11.95	12.20	13.34	13.03	11.91	11.00	9.39	8.82	9.06	9.20
Murcia	26.04	26.57	27.07	25.95	25.04	25.66	24.81	23.20	22.58	21.44	21.21
Navarra	17.34	17.16	17.29	16.85	16.55	18.25	18.24	15.79	15.11	14.84	14.20
País Vasco	15.84	16.30	16.42	16.41	16.48	17.24	16.77	14.78	13.55	12.43	12.67
Rioja	19.94	19.75	19.98	19.75	19.40	20.13	19.31	17.05	15.69	14.36	13.73
Average	21.99	22.19	22.60	22.08	21.69	22.36	21.81	19.94	18.79	17.79	17.73

Notes: The table shows the estimations for the shadow economy for each of the Spanish regions obtained from González-Fernández and González-Velasco (2015). Data are expressed as a percentage of regional GDP.

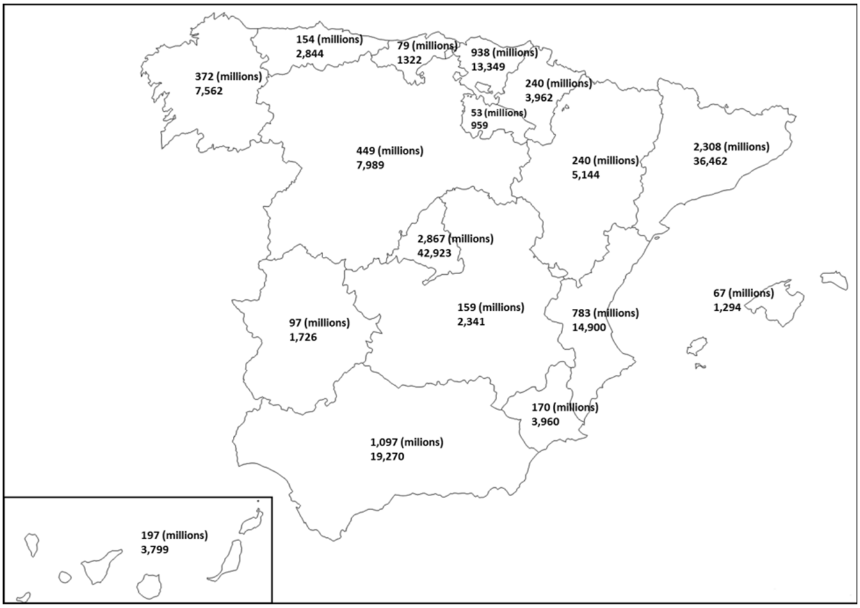
Source: González-Fernández and González-Velasco (2015).

Table A3 Mean Values of the Variables Included in the Analysis by Spanish Region

Regions	Growth patents (%)	Expenditure R&D/GDP (-2) (%)	FDI/GDP (%)	Total patents (N)	CPI (index)	CPJA (N)	SE (%)	CTA (N)
Andalucía	0.115	0.0018	0.0037	63.21	3.543	2 2000.00	0.279	50.69
Aragón	0.189	0.0015	0.0032	57.29	5.226	255.62	0.177	12.92
Asturias	0.093	0.0013	0.0132	14.94	5.330	274.77	0.210	9.30
Islas Baleares	0.129	0.0008	0.0112	8.51	5.022	250.46	0.201	7 200
Islas Canarias	0.189	0.0015	0.0032	9.15	4.877	452.62	0.291	4.07
Cantabria	0.947	0.0014	0.0015	8.19	5.424	148.46	0.225	2.07
Castilla La Mancha	0.137	0.0006	0.0028	16.17	4.992	377.38	0.223	7.69
Castilla y León	0.062	0.0008	0.0016	33.73	4.947	447.53	0.181	13.07
Cataluña	0.096	0.0017	0.0148	428.73	4.261	1 2360.46	0.172	49.92
C. Valenciana	0.033	0.0011	0.0075	104.88	4.868	1 2181.35	0.214	14.69
Extremadura	0.358	0.0018	0.0016	2.55	5.240	233.53	0.264	4.30
Galicia	0.162	0.0012	0.0047	28.65	5.022	605.07	0.238	13.00
C. Madrid	0.043	0.0045	0.062	238.81	3.789	687.46	0.111	53.53
Murcia	0.208	0.0013	0.0061	16.35	5.169	356.77	0.245	6.07
Navarra	0.094	0.0010	0.0037	47.57	5.189	129.38	0.165	3.53
País Vasco	0.061	0.0007	0.0063	122.47	4.624	475.30	0.153	14.69
La Rioja	0.422	0.0014	0.0019	6.30	5.468	72.00	0.180	2.23

Notes: The table displays the mean values of the variables included in the analysis by Spanish region. We show the values of the public expenditure on R&D relative to GDP 2 foreign direct investment (FDI) relative to GDP 2 the total number of patents 2 CPI growth in the Spanish regions 2 the number of crimes against Public and Justice Administration (CPJA) 2 the shadow economy related to GDP (SE) for the Spanish regions and the number of crimes against tax authorities (CTA).

Source: Authors' calculations.



Notes: The map shows the average values of the R&D investment in millions of euros and the total number of full-time R&D staff in number of employees by regions during the period of analysis (2000 to 2012).

Source: Authors' calculations.

Figure A1 R&D Staff and Investment by Region

Table A4 Correlation Analysis Findings for the Variables Included in the Regressions

Pearson correlations	1	2	3	4	5	6	7	8
1 Growth in patents (%)	1.0000							
2 Expenditure R&D/GDP (%)	-0.0576	1.0000						
3 FDI/GDP (%)	-0.0497	0.5222	1.0000					
4 Total patents (in logs)	-0.0962	0.3719	0 23435	1.0000				
5 Debt/GDP (%)	-0.0788	0.0685	0.0427	0.3759	1.0000			
6 Unemployment (%)	-0.0076	0.2183	-0.1219	-0.0818	0.5113	1.0000		
7 CPI (index)	0.1462	-0.5496	-0.3125	-0.6048	-0.2394	-0.3001	1.0000	
8 SE (%)	0.0591	-0.3559	-0.3433	-0.4761	-0.1530	0.2703	0.1229	1.0000

Notes: In the first part of Table 2 we show the Pearson correlations between the variables included in the analysis. We include the dependent variable 2 i.e. 2 the annual growth of patents along with the rest of right-hand-side variables 2 namely 2 public expenditure on R&D relative to GDP 2 foreign direct investment (FDI) relative to GDP 2 the total number of patents 2 the debt/GDP ratio 2 unemployment 2 the CPI in the Spanish regions calculated by González-Fernández and González-Velasco (2014) and the estimates for the shadow economy related to GDP (SE) for the spanish regions calculated by González-Fernández and González-Velasco (2015). We also estimate the pairwise correlation in the second part of Table 2 and the results do not differ from those shown in the table.

Source: Authors' calculations.

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