THE IMPACT OF "GREEN REGULATION" ON FIRMS' INNOVATION

2026

BANCO DE ESPAÑA
Eurosistema

Documentos de Trabajo
N.º 2611

Juan S. Mora-Sanguinetti, Cristina Peñasco
and Rok Spruk

THE IMPACT OF "GREEN REGULATION" ON FIRMS' INNOVATION (*)

Juan S. Mora-Sanguinetti (**)

BANQUE DE FRANCE AND BANCO DE ESPAÑA

Cristina Peñasco (***)

BANQUE DE FRANCE AND UNIVERSITY OF CAMBRIDGE

Rok Spruk (****)

UNIVERSITY OF LJUBLJANA

(*) This working paper reproduces the contents of the following article: Mora-Sanguinetti, J. S., Peñasco, C., and Spruk, R. (2024). "The impact of «green regulation» on firm innovation". *The Review of Industrial Economics/ Revue d'Économie Industrielle,* 188(4), pp. 39-87. The article was also published as a Banque de France - Eurosystem Working Paper, Working Paper, #1016. The views expressed in this Working Paper are personal and do not necessarily reflect those of the Banco de España, the Eurosystem or any affiliated institution.

(**) Juan.MORASANGUINETTI.external@banque-france.fr and juans.mora@bde.es. Tel.: (+34)913385197.

(***) Cristina.PENASCOPATON@banque-france.fr

(****) rok.spruk@ef.uni-lj.si

Documentos de Trabajo. N.º 2611

March 2026

https://doi.org/10.53479/42665

ISSN: 1579-8666 (online edition)

Abstract

This paper analyses the impact of “green regulations” - i.e. those aimed at mitigating the effects of climate change and environmental externalities - on innovation, using a novel regulatory database covering the period 2008-2022 for Spain. The database identifies regulations at both the national and regional levels through textual analysis. Employing a panel data approach, we assess how different types of environmental regulations - particularly those related to renewable energy - affect firm-level innovation activities. Our findings indicate that national-level green regulations have a positive effect on innovation, whereas regional-level regulations show mixed or negligible impacts. Importantly, the interaction between national and regional regulations, measuring the simultaneous production of legal texts at both levels, can foster innovation but at a reduced pace with respect to the sole production of regulation at the national level. Given the results for regional-level regulation, our findings provide evidence in favour of the hypothesis that regulatory fragmentation due to unequal, overlapping, inconsistent or conflicting procedure across jurisdictions may diminish these benefits.

Keywords: green regulation, innovation, Porter hypothesis, renewable energy, business.

JEL classification: K32, Q5, O44, O13.

Resumen

Este documento analiza el efecto de la normativa «verde», es decir, aquella destinada a mitigar los efectos del cambio climático y las externalidades medioambientales sobre la innovación empresarial. El análisis se fundamenta en una base de datos regulatoria inédita que identifica las normas a nivel nacional y regional (autonómico) para España (en el período 2008-2022) mediante técnicas de análisis textual. Adoptando un enfoque de datos de panel, evaluamos cómo los distintos tipos de normas medioambientales —en particular, las relacionadas con las energías renovables— influyen en las actividades de innovación de las empresas. Nuestros resultados indican que este tipo de normas a escala nacional tienen un efecto positivo sobre la innovación, mientras que las normas regionales presentan efectos mixtos o poco significativos. Es especialmente destacable que la interacción entre las normas nacionales y regionales puede favorecer la innovación, pero a un ritmo menor que cuando la normativa se establece únicamente a nivel nacional. Nuestros resultados sobre las normas regionales tienden a validar la hipótesis de que una fragmentación regulatoria excesiva —debida a procedimientos aprobados a ritmos desiguales o solapados, o contradictorios entre jurisdicciones— podría reducir los beneficios de la regulación.

Palabras clave: regulación verde, innovación, hipótesis de Porter, energías renovables, empresas.

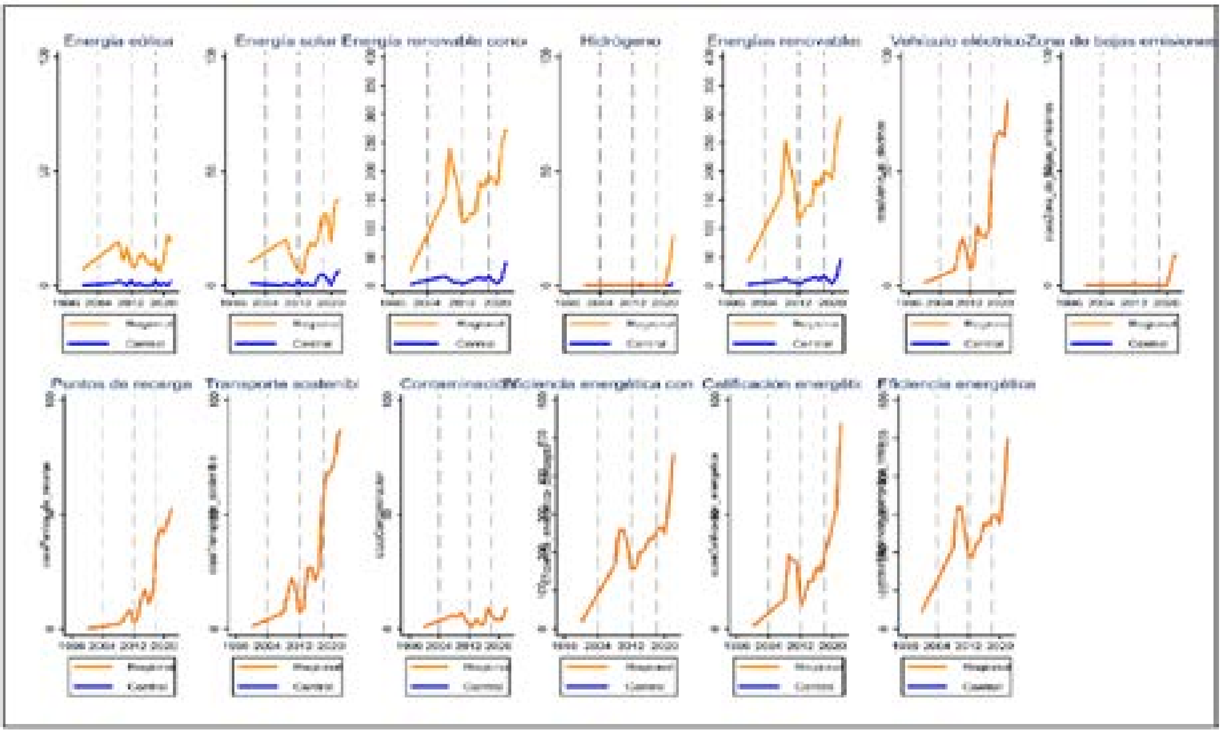
Códigos JEL: K32, Q5, O44, O13.

1. Introduction

The challenges posed by the climate change agenda are wide-ranging. On the one hand, there is the overarching goal of keeping global warming below 1.5 degrees Celsius [see, for example, UNFCCC (2015) or World Bank (2023)]. Alongside this, compatible targets have been set on a number of specific fronts, such as combating pollution or encouraging energy efficiency.

Although public administrations can put forward several strategies to achieve those objectives, the most common way in which they express their economic policies (in this case "green policies") is by using the vehicle of regulation [North (1981, 1990 and 1999)]. Generally speaking, regulation is used to mitigate market failures and reduce transaction costs. In the "green" context, regulation could be used to promote the spread and use of new, more energy efficient (or less polluting) technologies among firms. Therefore, it is of particular interest to know and systematize the legislative initiatives that are taking place in a developed economy in order to be able to analyze their effectiveness. From a negative point of view, it is equally useful to analyze and systematize regulations in order to understand their potential design trade-offs, as regulations that are not well designed could generate inefficiencies in companies and should thus be corrected (Peñasco et al., 2021).

Figure 1. Frequency of regulation by specific topic for both the national and the regional administrations



Source: Mora-Sanguinetti and Atienza-Maeso (2024a).

In a previous article, Mora-Sanguinetti and Atienza-Maeso (2024a) identified and systematized, through text analysis, the "green" regulations adopted in Spain, by the national and regional[4] governments, over the period 2000-2022 in four main areas: renewable energies, energy efficiency measures, sustainable transport policies and the fight against pollution.

By way of general conclusions from the analysis of Spanish green regulation, we know that this regulatory field is relatively "new". That is, regulatory activity began in a distinguishable way no earlier than the year 2000 (see Figure 1 in which the frequency of regulation is distinguished, both by subject and by level of administration within Spain). In Figure 1, the national regulations for each subject are shown in blue and the set of regulations adopted by the regional administrations in orange. Likewise, we can affirm that the growth since then has been

[4] Throughout this article, the terms 'region' and 'Autonomous Community' will be used interchangeably. Spain, as will be explained in more detail, is administratively divided into Autonomous Communities giving the country a political organisation similar to that of a federal state.

rapid, with the exception of some central years of the economic crisis and that there are relevant differences between administrations. This provides us, despite its relative "youth", with a good basis for analysis to compare different regulatory strategies and understand their business impacts.

It is, in particular, the impact on innovation in firms what we are interested in. Research has indicated that R&D plays a crucial role in facilitating productivity growth and promoting economic convergence across countries (Mc Morrow *et al*., 2009) and regions. Indeed, investments in innovation have been found to have a significant effect on environmental Total Factor Productivity (TFP), highlighting the interconnectedness of technological progress and environmental sustainability (Wu *et al*., 2022). For example, TFP growth is often associated with technical progress and advancements in technology, which are key drivers of economic development (Mustapha *et al*., 2013).

Innovation is widely recognized as a crucial driver of economic growth and competitiveness, particularly in the context of environmental sustainability. As global environmental challenges such as climate change, resource depletion, and pollution intensify, firms are increasingly pressured to innovate in ways that reduce their environmental impact. While innovation is often driven by market forces and technological advances, regulation plays a pivotal role in shaping the innovation landscape. Traditional perspectives have often viewed regulation as a constraint on business activity, imposing additional costs and potentially stifling innovation. However, the Porter Hypothesis (Porter and van der Linde, 1995) challenges this view by arguing that well-designed environmental regulations can actually spur innovation, leading to improved environmental outcomes and enhanced competitiveness.

In a recent report published by the European Commission (EC, 2024), Mario Draghi emphasizes the critical link between decarbonization, innovation, and competitiveness. It underscores the idea that environmental sustainability should not be seen merely as a regulatory burden but as a strategic opportunity for enhancing long-term competitiveness. The report argues that Europe's ambitious climate goals—if supported by coherent policies—can catalyze the growth of clean technologies, creating a competitive advantage in global markets. However, this requires effective coordination between different levels of governance, both national and subnational. Fragmented regulations, understood as those regulatory situations where regulations are unequally developed, or may even introduce overlapping, inconsistent or conflicting procedures across different jurisdictions or levels of government, risk increasing compliance costs and diluting the impact of innovation efforts. However harmonized and strategically aligned policies can foster a regulatory environment that promotes sustainable innovation. From the perspective of the economic analysis of law, concerns about the negative consequences of possible market fractures have inspired fundamental rules for European citizens. It is worth mentioning both those corresponding to the construction of the EU single market itself (e.g., Directive 2006/123/EC on the Internal Market), as well as national legislation. In Spain, the Constitution expressly establishes that the authorities must avoid measures that could break with the freedom of establishment or compromise the movement of goods within Spanish territory.[5] The basic economic reasoning is clear: a "broken" market - in the sense of a market divided by different applicable norms (and therefore firms would have to learn different norms to be able to operate in different regions)- would be divided in smaller portions threatening the growth and specialization capacity of firms (Becker and Murphy, 1992; Laeven and Woodruff, 2007).

Indeed, the interaction between national and subnational regulations adds a layer of complexity to this relationship. National regulations may establish a uniform baseline across a country, ensuring that all firms adhere to minimum standards. These regulations may be essential for maintaining a level playing field and addressing environmental issues that require coordinated, large-scale action (Goulder and Stavins, 2011). However, subnational regulations may vary significantly, reflecting local environmental conditions, political priorities or economic contexts. This variation may create opportunities for regulatory innovation at the subnational level, where more stringent or tailored regulations may push firms to develop new technologies and processes that may be specifically suited to their operating environments (Lehmann and Gawel, 2013).

Therefore, the interaction between national and subnational regulations may have both positive and negative effects on innovation. On one hand, when these regulations are harmonized and complementary, they may create a regulatory environment that fosters innovation by providing clear incentives and reducing uncertainty (Ashford and Hall, 2011). For instance, in the European Union, national governments often implement additional measures that build on EU-wide environmental directives, creating a multi-layered regulatory framework that encourages innovation in sectors such as renewable energy and emissions reduction (Veugelers, 2012). On the other hand, fragmented or conflicting regulations between national and subnational levels may increase compliance costs and

[5] Article 139.2 of the Spanish Constitution establishes that "No authority may adopt measures that directly or indirectly hinder the freedom of movement and establishment of persons and the free movement of goods throughout Spanish territory".

create uncertainty for firms, potentially diverting resources away from innovation (Burtraw and Evans, 2009). The relationship then between environmental regulation and innovation seems complex, and could infer varying impacts depending on the industry characteristics, firm-specific factors and the type of regulation. For the purpose of this paper is in the latter that we are going to focus on.

The objective of this article is to understand the degree of success of environmental regulatory frameworks in Spain, in particular the regulation to boost the adoption and development of renewable energy, in innovation in the business context in Spain. This paper aims to explore the complex interaction between national and subnational environmental regulations and their joint impact on fostering innovation within firms in Spain using a panel data at the regional level from 2008 to 2022. The impact of the type of regulation from a multi-level governance perspective will be studied. This study seeks to provide insights into how multi-level and/or multi-purpose regulatory frameworks can either stimulate or hinder innovation in the business sector in Spain, offering valuable lessons for policymakers aiming to balance environmental protection with economic growth in multi-layered governance frameworks. We will then be able to understand whether green regulation is achieving the objectives of changing the business ecosystem. To the best of our knowledge this is the first paper trying to disentangle this relationship at the regional level in firms in Spain. While this exercise is necessarily exploratory, their implications may be extrapolated to other international contexts with similar multi-level governance characteristics. The rest of the article is structured as follows: section 2 includes the theoretical framework and a short review of the literature. Section 3 presents the data and methods, including a summary of the results of the regulatory database presented by Mora-Sanguinetti and Atienza-Maeso (2024a). Section 4 present our results. Finally, section 5 concludes.

2. Theoretical framework and literature review

Schumpeter's seminal work on innovation underscored its critical role as a driver of economic development and growth. Schumpeter (1934) argued that innovation—the introduction of new products, processes and business models [see (OECD/Eurostat, 2018) for a detailed definition]—serves as the primary engine of economic progress. He conceptualized innovation as a disruptive force, often referred to as "creative destruction", where new technologies render existing ones obsolete, thereby driving economic dynamism (Schumpeter, 1942).

In this framework, entrepreneurs are the key agents of innovation, constantly seeking to exploit new opportunities through innovative activities. However, the institutional environment in which these entrepreneurs operate, thus including the regulatory landscape, plays a significant role in either facilitating or impeding innovation [see Ardagna and Lusardi (2010) or García-Posada and Mora-Sanguinetti (2014)]. Schumpeter acknowledged that regulation could have a dual impact: while excessive regulation might stifle innovation by imposing constraints and increasing costs, well-designed regulations could stimulate innovation by providing clear guidelines and incentives for technological advancement (Schumpeter, 1947). The relationship between regulation and innovation is complex. On one hand, stringent regulations may increase the costs of compliance, thereby reducing the resources available for firms to invest in research and development (R&D). On the other hand, regulation may also act as a catalyst for innovation by encouraging firms to develop new technologies or processes to meet regulatory standards (Porter and van der Linde, 1995). This positive view is encapsulated in the Porter Hypothesis, which posits that well-designed environmental regulations can lead to innovations that partially or fully offset the costs of compliance, potentially even improving competitiveness.

The theoretical underpinning for the positive impact of regulation on innovation can also be linked to the concept of "induced innovation," where firms are motivated to innovate in response to external pressures, such as regulatory requirements (Grubb *et al*. 2021). Thus, regulation, when designed effectively, can create a market for innovation, particularly in sectors where technological advancements are necessary to comply with new standards, i.e. environmental innovation.

2.1. The Role of Environmental Regulation on Innovation in Firms

Environmental regulations have increasingly been recognized as key drivers of innovation within firms, particularly in the context of eco-innovation. The Porter Hypothesis posits that well-designed environmental regulations not only enhance environmental performance but also stimulate firm competitiveness by driving innovation (Porter and van der Linde, 1995). Recent empirical studies provide substantial support for this claim, highlighting how firms respond to regulatory pressures by investing in eco-innovations that reduce environmental impact while improving operational efficiency and market competitiveness (Cecere *et al*., 2014; Del Rio et al., 2015). A growing body of literature explores the impact of environmental regulation on firm innovation, particularly focusing on the relationship between the number of regulations and innovation outcomes. Unlike studies that examine the stringency of regulations, research on the quantity of environmental regulations is an emerging area of research that suggests that the cumulative regulatory burden can act as both a driver and a barrier to innovation. One of the possible ways to measure regulatory complexity is to quantify the number of norms (although complexity can also come from the linguistic complexity of the texts or the structure of connections that the rules establish). Regulatory complexity may influence firms' decisions to innovate as they try to meet multiple requirements (Mora-Sanguinetti, 2019; De Lucio and Mora-Sanguinetti, 2022).

The presence of multiple environmental regulations can create complex compliance landscapes for firms. On one hand, a higher number of regulations can increase regulatory pressure, incentivizing firms to develop innovative solutions that address various environmental issues simultaneously. Firms are often compelled to invest in eco-innovation to navigate the diverse set of rules and to comply more efficiently across multiple regulatory frameworks (Ghisetti and Quatraro, 2017; De Marchi, 2012; Rennings and Rammer, 2011). According to Del Río *et al*. (2016), the presence of multiple environmental regulations signals to firms that there is a sustained institutional commitment to environmental protection, pushing them to adopt eco-innovations not only for compliance but also as a strategic measure to improve competitiveness and sustainability.

In particular, eco-innovation, which includes the development of products and processes that reduce environmental impact (Carrillo-Hermosilla *et al*. 2009), is particularly sensitive to regulatory frameworks. As firms encounter a greater number of regulations, they often engage in innovations that allow them to comply with multiple requirements simultaneously. For instance, regulations targeting emissions, waste reduction, and resource efficiency may prompt firms to develop integrated solutions that address all these areas (Rennings, 2000). However, there are limits to this positive effect. In some cases, the sheer volume of regulations can overwhelm firms, especially smaller ones, leading to increased administrative burdens that divert resources away from R&D and innovation (Blind, 2012).

While firms may initially view a high number of regulations as a challenge, the cumulative effect often promotes incremental innovations that enhance compliance in cost-effective ways (Horbach et al., 2012). Additionally, firms in sectors with higher regulatory pressure tend to invest more heavily in R&D for eco-innovation (Cainelli et al, 2012). These innovations often become a competitive advantage, as environmentally friendly products and processes are increasingly demanded by consumers and stakeholders.

A growing body of literature indicates that national and regional environmental policies significantly influence the innovation performance of firms, particularly in industries with high environmental externalities, such as manufacturing and energy (Albrizio *et al*., 2017). Firms in heavily regulated environments are often compelled to increase their research and development (R&D) spending to develop innovative solutions that reduce emissions or resource use (Zeng et al., 2021). Additionally, many firms see environmental regulation as a means to differentiate themselves in the marketplace, offering more sustainable products or services that align with rising consumer and investor demand for environmental responsibility (Ghisetti and Montresor, 2020).

Consequently, as a first hypothesis, we will analyze whether: (Hypothesis 1, H1) firms subject to a higher number of environmental regulations will exhibit higher levels of innovation compared to contexts where there are fewer regulatory requirements.

2.2. The Role of Multi-Level Governance in Shaping Firm Innovation

Multi-level governance, characterized by the involvement of various government levels (local, regional, national, and supranational) in policymaking, plays an essential role in shaping firms' innovation activities. The number of regulations that firms face is often a result of this layered governance, where regulations are imposed by multiple governing bodies. This can either foster innovation through complementary policies or create challenges due to regulatory complexity and overlap. Del Río (2009) highlights that multi-level governance can enhance eco-innovation when there is coordination between governance levels, ensuring that firms receive consistent signals regarding environmental goals and priorities. For example, firms in regions where local and national regulations align are more likely to innovate effectively because they face a coherent set of rules. Conversely, fragmented governance, where different regulatory bodies impose conflicting requirements, can create uncertainty and stifle innovation (Kivimaa and Kern, 2016).

In regions where multiple environmental regulations are imposed by different governance levels, firms may experience a regulatory burden that prompts innovation to efficiently meet diverse requirements (Borrás and Edler, 2014). For instance, firms operating within the European Union often navigate both national regulations and supranational policies such as the EU Emissions Trading Scheme. While this increases the number of regulations firms must comply with, it also provides opportunities for them to innovate by adopting technologies and practices that meet both local and international standards (Rogge and Reichardt, 2016). However, an excessive number of uncoordinated regulations across governance levels can lead to inefficiencies. Firms may struggle to innovate if they are uncertain about which regulations will persist or if they face conflicting goals from local, national, and supranational bodies [see Flanagan *et al*. 2011; in addition to more general Law & Economics references highlighting the potential problems of coordination: Ellingsen (1998) or Di Vita (2018)]. Effective multi-level governance, where regulations are harmonized and provide clear and stable frameworks for innovation, is critical for encouraging firms to invest in long-term eco-innovative solutions.

Consequently, as a second hypothesis, we will analyze whether: (Hypothesis 2, H2) whether the joint production of regulation at national and regional level has a positive effect on firms' innovation. Such a hypothesis is important to test in order to assess the consistency of regulatory frameworks and conveys important policy-relevant implications concerning their efficacy, notably regarding which level matters and to what extent regulations develop in tandem (e.g. in case of transposition), or exhibit delays and/or even contradict.

3. Data and methods

3.1. Data

The proposed hypotheses in section 2 are tested using a newly compiled data that covers the regulations by category of environmental technology/purpose and by region over the period 2008-2022 in Spain (both at the national and regional levels) (see Tables A1 and A2 in the appendix for additional information). We complement the information provided by Mora-Sanguinetti and Atienza-Maeso (2024a) with data for the dependent and control variables coming from the "Encuesta de Innovacion en la Empresa" (Enterprise Innovation Survey) of the Spanish National Statistics Office (INE) and from the Regional Accounts provided by Eurostat.

3.1.1. Main independent variable: Identifying "green regulation"

There are still few databases that summarize large volumes of regulation in statistical format. At a disaggregated level, i.e., classifying regulation by region/state-national level (within a federation) or by topic/sector (also exploiting regional or national variation) we can mention the databases for the case of the United States [Dawson and Seater (2013), McLaughlin et al., (2019)] and Spain [Mora-Sanguinetti et al. (2024) and Mora- Sanguinetti and Atienza-Maeso (2024b)]. Mora Sanguinetti and Atienza-Maeso (2024a) provide a first comprehensive database on specifically "green" regulatory adoption through text analysis providing information both at the specific regulatory policy level, by region and by year (i.e., three dimensions).[6] This database will be used in this article to capture our main independent variable. This dataset, thanks to the aforementioned text analysis technique, can capture the regulations with a very high level of completeness [see Mora Sanguinetti and Atienza-Maeso (2024a) for details on the database construction]. The regional level is the majority or dominant level in Spain.

Spain is a *de facto* federal country (legally, it is a regionalized political system) in which the regions issue many more regulations than the central administration (see Mora-Sanguinetti and Spruk, 2023). For further clarification, with the new democratic period and the 1978 Constitution, Spain established a system of executive and legislative power divided between the central administration and the regions ('Comunidades Autónomas'). The Constitution and the regional constitutions (the "Statutes of Autonomy") establish the basic list of powers of each level of administration.[7] Both levels of government can pass laws. One difference from the federal system is that in the system of autonomies, regions can potentially have different powers from each other. It is also characteristic of the system of autonomies that there may be shared powers between the national and regional administrations (López-Guerra et al. 2018). The evolution of the system over the decades in Spain has resulted in a country as decentralized as the federal ones (Hooghe et al. 2008)[8].

[6] At the thematic level (specifically "green" issues) and focusing only on regulation (not on other policies), a comparable database was that proposed by the CCLW - "Climate Change Laws of the World" database project. Law and Policy Search - Climate Change Laws of the World (climate-laws.org) https://climate-laws.org/. Similarly, see the "Climate Policy Radar" (Climate Policy Radar | AI for climate law and policy research). CCLW provides a country-level database that identifies key national regulations. The coverage results in 16 regulations for Spain. This contrasts with the thousands of results that we can find with text analysis.
[7] The subjects regulated by national and regional regulations are to a large extent different (see Mora-Sanguinetti and Atienza-Maeso (2024a). For example, national law establishes the basic rules for the protection of the environment (Article 149 of the Spanish Constitution). But regional regulations may undertake powers in the management of environmental protection (article 148 of the Spanish Constitution).
[8] In the "Regional Authority Index", Spain's score is similar to that of Canada or the USA.

As evidence of the "regionalized" nature of Spain (and the source material from which the "green" regulation indicators are constructed), for the period considered (2008-2022), the Spanish regions adopted 140,898 regulations in total (green or any other type), compared to the central administration, which adopted 33,001 regulations (green or any other type).

As a result, Mora-Sanguinetti and Atienza- Maeso (2024a) identified, for example, 5,116 norms related to the measurement of energy efficiency or 3,482 norms related to renewable energies. See Table A1 in the appendix for a summary of the norms found and classified (by thematic block and administration). As can be seen in the table, the regulation is classified in four major topics: 1) renewable energies, 2) sustainable transport, 3) pollution, 4) energy efficiency. They identify the norms based on key concepts and phrases extracted from the texts of all the norms published in the Official Gazettes of both the State (national level) and the regions (from Aranzadi La Ley). The norms identified have the force of law -i.e. laws or rules which, according to the legal system, have equivalent status (and can repeal lower-ranking rules)- or less than the force of law[9]. This strategy is in common with other previous research work and specifically with the literature on measuring the "complexity" of the regulatory framework (see, for example, De Lucio and Mora-Sanguinetti, 2022).

Regarding the territorial dimension of the data, we can confirm that there is a great variety by administration (region). This would allow to explore and exploit market discontinuities (as a result of the decentralization of the administration in Spain).[10] The potential effects of these discontinuities have been studied for the case of firms by Becker and Murphy (1992), Vallés and Zárate (2012) or Mora-Sanguinetti and Valls (2021). Regarding the time dimension, the database (Mora-Sanguinetti and Atienza-Maeso, 2024a) shows that around the year 2000 there was hardly any regulatory activity regarding "green" issues. We can identify that regulatory activity starts in a distinguishable way from 2008 onwards, especially in the case of renewable energies. For the rest of the subjects, it will be necessary to wait until the second decade of the 2000s to observe relevant regulatory activity. This is the main reason why for the purpose of this analysis we focus on renewable energy regulation[11].

The variations at both the temporal and territorial dimensions give us an interesting panel perspective that we can exploit to understand the effects of "green" regulations, and in particular, regulations to boost the development and adoption of cleaner energies, on firms' innovation and their incentives. In terms of the practical operation of the Spanish legal system, it should be noted that the activities[12] of a firm located in a given region "i" will be subject to region-specific regulation (enacted by the region "i") as well as national regulation. In this article, as it deals with the exclusive case of Spain, the possible harmonising effects of EU regulations at the international level are not discussed.[13]

For the purpose of this paper we focus in particular on renewable energy regulation, one of the most dynamic sectors in Spain in recent decades. Table A2 in the appendix includes the descriptive statistics of the regulatory database.

3.1.2. Main dependent variable: Innovation Expenditures in Firms by Region

The main objective of the "Encuesta sobre Innovacion en las Empresas" is to offer direct information on the innovation process in companies, developing indicators that allow us to understand the different aspects of this process (economic impact, innovative activities, cost, etc.)[14]. To fully grasp the essence of innovation, it is necessary to examine a range of indicators that span the entire innovation process. Focusing on just one indicator might lead to an incomplete understanding. Innovation processes are complex processes structured, mainly, in five different stages connected through non-linear dynamic relationships. These stages are: research, development, demonstration, market formation, and diffusion (Grübler *et al*., 2012). Each stage forms an important part of the

[9] The Mora-Sanguinetti and Atienza-Maeso (2024a) database includes norms coming from the executive. For example, the Order (Madrid) 2993/2021 of 6 October ("Approves the strategic plan for the direct award of grants linked to Next Generation EU funds"), comes from the Regional Minister for Education, Universities, Science and Government Spokesman.

[10] Mora-Sanguinetti and Atienza-Maeso (2024a) also provide a classification and compilation of "green" regulations for the case of the French market. France is a significantly more centralized country than Spain. The database provides evidence that the volume of state-level regulations adopted by the General State Administration in Spain and in France are comparable. The differential fact is the large volume of "green" regulations (with the force of law) published by the Spanish regional administrations (which we exploited for our analysis).

[11] The analysis can be replicated for other type of regulations included in Mora-Sanguinetti and Atienza-Maeso (2024a).

[12] Both in the "Encuesta de gasto I+D" ('R&D Expenditure Survey') and in the "Encuesta de innovación en las empresas" ('Business Innovation Survey'), R&D resources are regionalised (we observe them in each region). That is, grosso modo, they are specifically affected by the regional regulation of the region concerned.

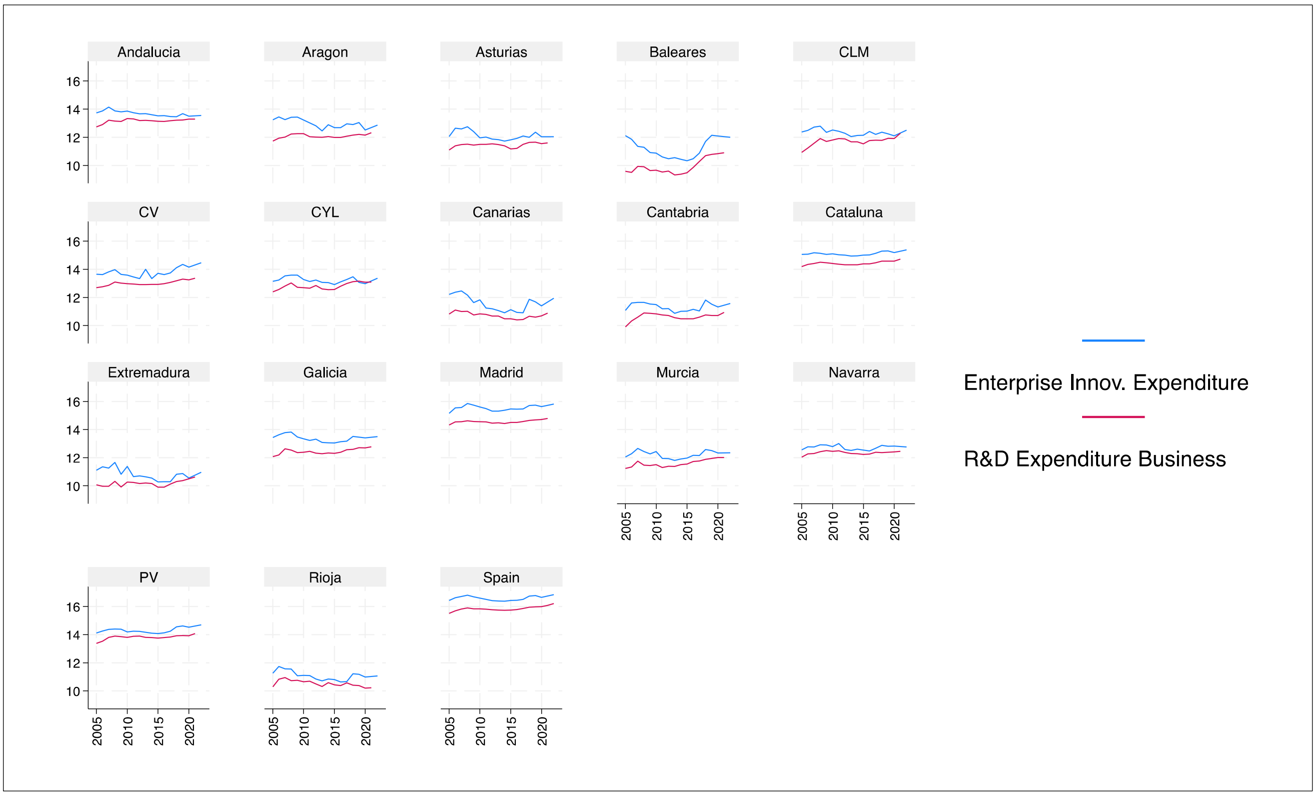
[13] On the other hand, by way of clarification, EU Directives, insofar as they have to be transposed into national law, would be reflected in Spanish national norms or in regional norms (depending on which administration has the specific power according to the Constitution and the statutes of autonomy).

[14] The methodology of the 'Encuesta sobre Innovacion en las Empresas' follows the Guidelines proposed by the OECD for the collection and interpretation of data on innovation, better known as the Oslo Manual [see OECD/Eurostat (2018)].

innovation process and can be measured by different indicators e.g. R&D investments, patents, or cost reductions among others.

R&D expenditures or the number of personnel on scientific roles are, in addition to patents, common measures used as a proxy of innovation. However, up to now, there is no agreement about the optimal variable and all of them present limitations (OECD, 2009). Public and private investments in research and development (R&D) are crucial for fostering a cleaner and more productive transition to decarbonized economies. Public R&D investments are known to encourage technological innovation in the private sector (Rehman et al., 2020). Studies have shown that R&D subsidies can effectively stimulate private R&D spending and act as an enable, indicating a positive relationship between public support and private R&D investments (Lach, 2002).

Figure 2. Innovation and R&D expenditure by region in the business enterprise sector, 2005-2022



Source: own elaboration with data from INE and Eurostat. The line in blue represent the natural logarithm of the innovation expenditure per region by enterprises while the red line represents the natural logarithm of the expenditure in R&D performed by the business sector in '000 eur .

On the other hand, private R&D expenditures are essential for sustainable economic growth (Ravšelj & Aristovnik, 2018). They are vital for driving innovation, productivity, and competitiveness in various sectors (Qiu *et al*., 2014).

It is these private innovation and R&D metrics that we will pay attention to. For the purpose of this paper we will use the innovation expenditure in firms by region where the expenditure was disbursed (InnE). Innovation activities are understood in the Spanish Survey of Innovation in Firms as any activity (financial, development or commercial) that leads to the development or adoption of innovations. It includes seven different activities: internal research and experimental development (R&D); acquisition of R&D (or external R&D); engineering, design, and other creative activities; marketing and brand creation; activities related to intellectual property rights; activities related to staff training; software development and activities related to the work of databases and activities related to the acquisition or leasing of tangible goods (INE methodological notes). Additionally, the number of R&D personnel in the business sector (RDPer) as along with R&D expenditure by the business enterprise sector (RDE) are also included as alternative dependent variables. Figure 2 show both the expenditure on innovation at the firm level by Spanish regions and the business enterprise sector expenditure on R&D by region. Table 1 summarizes the descriptive statistics. A correlation matrix can be found in the appendix as well as a more elaborated table including detailed definitions (Table A3).

Table 1: Descriptive statistics[15]

Variable	Unit	Obs.	Mean	Std. dev.	Min.	Max.
Dependent variable						
Innovation expenditure (InnE)	'000€	238	950459.7	1546206	28954	7665642
Alternative dependent variables						
R&D personnel FTE business (RDPer)	FTE	238	5638.124	7331.84	220.1	29563
R&D expenditure business (RDE)	'000€	238	456913.7	639263	11120	2642843
Independent variables						
Reg. renewables national (RRenNac)		255	39.46667	24.58902	13	101
Reg. renewables regional (RRenReg)		255	11.03529	6.402104	1	47
Other control variables						
GDP mp vol business (GDP)	Index	255	104.5565	9.084782	81.7	151.9
Capital formation business (K)	'000€	238	2425378	2144230	202187	9446510
Employment business (Employ)	'000 people	255	133.4537	120.3529	23.7	626.3
Labour productivity per hour (Prod)	Index b. 2015	255	98.46078	4.031992	86.9	107

Source: own elaboration.

3.2. Methods

The Cobb-Douglas (Cobb and Douglas, 1928) production function has been a foundational model in economics for representing the output of a production process. In our setup, instead of considering output or productivity-specific outcomes, we embed the innovation expenditure in the standard production function model. Using the expenditure-based outcomes, the aim of our empirical strategy is to examine the contribution of regulatory dynamics to the innovation fiscal capacity. Compared to the traditional approach to study the creative destruction (Aghion and Howitt 2023) where patents are used to proxy knowledge-specific assets, our primary interest lies in the identification of the nexus between the production of legal rules and innovation-enhancing fiscal capacity. By empirically calibrating our model to the disaggregated granular-level data, the chief advantage of our model is posited by the ability to identify the expenditure elasticity of regulation which can be reconciled with the prior literature and discussed empirically whilst policy implications for the growth of total factor productivity can be assessed.

In the simplest form under Harrod-neutral technological progress, innovation expenditure function takes the following form:

$$Y = AK^{\alpha}L^{\beta} \qquad [1]$$

Where Y represents the expenditure variable, A is the level of total factor productivity, K represent the physical capital and L is the labor supply whereas α and β capture output elasticities with respect to capital and labor. To analyze the impact of regulation on innovation, we extend the Cobb-Douglass production function framework to incorporate innovation expenditure as the primary outcome variable of interest. Specifically, we model the

[15] See Table in Appendix 3 for a more detail definition of the dependent variables.

innovation as a function of regulation, reflecting the notion that regulatory environment can systematically influence both the level and direction of innovation dynamics within firms or industries.

To this end, we propose a model where the level of innovation is incorporated into the production function as follows:

$$Y = AI^{\gamma} K^{\alpha} L^{\beta} \qquad [2]$$

Where I represents the level of innovation and γ is the elasticity of expenditure with respect to innovation. Our key assumption is that the level of innovation is influenced by regulation as theoretically motivated by Schumpeterian and Porterian perspectives where upon the level of regulation follows a simplified Brownian law of motion:

$$I = I_0 \cdot R^{\delta} \qquad [3]$$

Where I_0 is the base level of innovation, R is the regulation variable and δ is the elasticity of innovation with respect to regulation. Substituting into the production function yields a simplified version of the production function:

$$Y = A\left(I_0 \cdot R^{\delta}\right)^{\gamma} \cdot K^{\alpha} \cdot L^{\beta} \qquad [4]$$

Or:

$$Y = \left(AI_0 \cdot R^{\delta}\right)^{\gamma} \cdot K^{\alpha} \cdot L^{\beta} \qquad [5]$$

Taking the logarithm of left- and right-hand side variables, the empirically operationalized version of the model becomes as follows:

$$\ln Y = \ln A + \gamma \ln I_0 + \gamma\delta \ln R + \alpha \ln K + \beta \ln L \qquad [6]$$

Which forms the basis for the empirical investigation of the relationship between regulation, innovation, and economic output. It should be noted that the regulation parameter can be either $\delta > 0$ if regulation tends to enhance R&D expenditure or $\delta < 0$ if the regulation hampers firm-level R&D investment. The sign of the δ coefficient is crucial since it will determine the joint expenditure elasticity parameter. Our empirical operationalization of the Cobb-Douglas production function embeds both the regulation and factor input variables enriched with the full set of unobserved effects. It takes the following form:

$$ln\, Y_{i,t} = \theta_{i,t} + \sum_{t=1}^{k} \mu_k \, ln\, Y_{i,t-k} + \lambda \cdot R_{i,t} + \mathbf{X}'_{i,t}\beta + \pi_t + \delta_i + \varepsilon_{i,t} \qquad [7]$$

where Y denotes the respective expenditure variable, θ is time-varying total factor productivity term capturing the level of technology, μ_k denotes the coefficient on k-th lagged outcome variable where $k = 1,2, \dots K$, and **X** is the vector of structural control variables. Our key parameter of interest is λ which captures the contribution of regulation, denoted by R, to R&D expenditure. The terms π_t and δ_i indicate both time-fixed effects and region-fixed effects, and capture unobserved heterogeneity bias that could taint the relationship between renewable energy regulation on innovation outcome. Stochastic disturbances are assumed to be identically and independently distributed and are denoted by $\varepsilon \sim i.i.d.$

In this study, we test the relationship where productivity drives R&D expenditures, a departure from the traditional view that R&D is a primary driver of productivity growth. This approach is grounded in the understanding that R&D investments are often endogenous, influenced by firm-level resources and broader economic conditions. Higher productivity generates increased profits and available resources, enabling firms to invest in R&D to sustain or enhance their competitive advantage. This feedback loop aligns with endogenous growth theory, which recognizes the bidirectional relationship between innovation and productivity (Aghion & Howitt, 1992). Empirical evidence also suggests that productivity gains can precede increased R&D spending, reflecting firms' capacity to allocate surplus resources toward innovation (Crepon, Duguet, & Mairesse, 1998). By testing the reverse causality, we aim to provide new insights into how productivity growth can shape firm-level innovation strategies, offering implications for policies that emphasize productivity-enhancing reforms as a means to indirectly stimulate R&D investment. Against this backdrop, our model can be used to assess first-order implications of the regulatory dynamics for R&D expenditure which bends directly on the growth of total factor productivity. In particular, if the changes in the regulatory dynamics invoke immediate or more gradual effects on R&D expenditure, such shifts conveys immediate implications for the growth of TFP to determine in which direction the changes regulatory dynamics affect TFP dynamics and firm-level innovation. In this respect, our approach complements standard analysis (Aghion and Howitt 1992) by looking at the innovation expenditure as the primary estimand of interest rather than patent stock. Since firm-level patent stock directly mirrors firms' willingness to invest in R&D, our focus on R&D expenditure is reflective of the firms' willingness to invest in R&D which reveals a prospective stock of knowledge and know-how rather than the actual one embedded in the standard analysis.

4. Estimation and results

Our strategy consists of estimating Equation (7) for each of our dependent variables i.e. different indicators of innovation; and identifying whether differences in the response to national and regional renewable energy regulation exists. For this purpose, we use, firstly, a set of OLS homogeneous estimators to follow with GMM-based estimators. Alvarez and Arellano (2003) show that the GMM-based estimators are consistent when, as in our case, $0 < T/N < 2$, where T is the number of years (15 with our data) and N is the number of cross sections (17 regions). Table 2 reports the estimated effect of regulation (at the regional level, RRenReg, and at the national level, RRenNac) on the pace of innovation using expenditure and R&D employment-related indicators. More specifically, the table reports the impact of renewable energy regulation at the national and regional level on the innovation indicators by estimating both fixed-effects and random-effects specifications. The evidence indicates a positive and statistically significant effect of national regulatory volume on innovation expenditure on the range of [0.0780, 0.117] ($p<0.1$), R&D expenditure [0.116, 0.134] ($p<0.01$) and R&D employment [0.0799, 0.111] ($p<0.01$). By contrast, the estimated effect of region-level regulatory volume on innovation expenditure [0.0429, 0.0464] ($p>0.1$), R&D expenditure [0.0195, 0.0328] ($p>0.1$) and R&D employment [0.0128, 0.0289] ($p>0.1$) appears to be statistically insignificantly different from zero, and does not indicate discernible increases in innovation in response to the changes in the respective regulatory volume.

This may be due to the nature of the regulations implemented in Spain during the period of analysis. There may be differences between the regulatory strategies of the regions and the central administration as well as differences in the portfolio of competencies of each administration.[16]

Columns (1) and (2) indicate that additional renewable energy regulation at the central level tends to boost the innovation expenditures in enterprises, respectively. Whereas standalone coefficients on region-level regulatory volume do not exhibit conventionally statistically significant effects, columns (3) and (4) report the interaction effect between central- and regional-level renewable energy regulation which appears to be positive and statistically significant at 10% [0.0185, 0.0226] ($p<0.1$). In addition, the evidence from columns (5) and (6) further reinforces the positive effect of national renewable energy regulation on innovation by indicating that increasing the national regulatory volume by 1 percent is associated with an increase in private-sector R&D expenditure by 0.11 percent and 0.13 percent, respectively. Whilst the independent effect of regional regulation cannot be statistically differentiated from zero, the interaction effect of regional and national regulation appears to be positive as indicated in columns (7) and (8) [0.0206, 0.0238] ($p<0.1$). Furthermore, columns (9) and (10) suggest that Autonomous Communities with a greater leverage of renewable energy regulation tend to undergo a more rigorous and statistically significant increase in the share of R&D personnel. In the presence of unobserved effects, our estimates suggest that 1 percent increase in renewable energy legislation is associated with around 0.8 percent increase in the share of R&D employment share, respectively. Columns (11) and (12) further indicate a positive interaction effect of national and regional regulation on R&D employment that appears to be statistically significant at conventional levels [0.0199] ($p<0.05$). Across the multitude of our specifications, we do not find evidence of statistically significant contribution of the physical capital to the innovation expenditure as the estimated coefficient on the physical capital stock is negative but statistically indistinguishable from zero. The estimated magnitude is not surprising for several reasons. First, R&D investment typically concerns intangible assets which do not seem to be particularly strongly sensitive to the cost of capital to same degree as the investment in tangible benefits where a lower degree of asset specificity can be found. Second, the innovation expenditure appears to react relatively more strongly to the size and composition of the labor force and the cyclical factors as region-level GDP fluctuations. At the same time, since the demand for R&D scales negatively on the relative price of capital, negative capital cost shocks will only amplify the importance of the regulatory framework in shaping the prices of R&D-specific goods and services since firms usually switch to less costly substitutes of capital-

[16] Note, in any case, that we do not make an internal classification of regulation between rules that subsidizes activities and other rules that prevent them. In our analysis we concentrate on the effect of the total volume of regulation per administration, with the intention of understanding the impact of the regulatory 'activism' of administrations and the possible impacts of regulatory fragmentation.

intensive investment. Against this backdrop, the size and significance of the coefficient on labor supply is not surprising as it is reflective of the positive and large effect of the skilled labor and its demand as the vehicles of private R&D expenditure (Acemoglu and Restrepo 2019). In particular, as the development of technology creates a displacement effect, the tasks necessary to complete the production process amplify the importance of labor in those tasks where labor has a comparative advantage over physical capital. Under neutral form of technological progress without factor augmentation, new tasks are generated via the reinstatement effect. Since R&D expenditure requires continuously evolving new forms of tasks, new forms of more differentiated and highly skilled labor are needed to satisfy the increasing demand which implies the increasing importance of labor share for firm-specific innovation as we identify across the full multitude of our specifications. Therefore, the labor coefficient in the range between 1.5 and 2 is not surprising. All in all, these results support H1 (in relation to national regulation) confirming that firms subjected to a higher number of national environmental regulations exhibit higher levels of innovation compared to contexts where there are fewer regulatory requirements at the national level. While regional regulations do not show the same pattern.

To test hypothesis 2, we first analyze the correlation between national and regional-level green regulations, which informs the interpretation of our interaction term. It should be noted that the interaction term in our analysis measures the simultaneity of legal text production at the national and regional levels, highlighting how both levels of regulation may either align or conflict with one another. We recognize that the interaction effect could indicate the potential for contradictory or inconsistent regulations between levels, which could affect the overall regulatory impact on firm-level innovation.

To shed light on this issue, we examine the correlation between national and regional regulations which appears to be small (i.e. 0.137, see correlation coefficient in correlation matrix in Appendix Fig. A1). Therefore, the findings from our analysis suggest that while national regulations have a predominant effect on innovation, regional regulations, when introduced alongside national ones, tend to exhibit a weaker and less consistent impact than national regulation alone.

The positive but attenuated effect of the interaction between renewable energy national and regional regulation, relative to the effect of national regulation alone, suggests a potential diminishing marginal return when both levels of regulation are simultaneously in place. This contradicts H2, but may also express that regulation are developed at different speed at national or regional levels[17] This may reflect overlapping or redundant policy frameworks, which can reduce regulatory clarity or increase compliance complexity for firms. While the combined presence of national and regional regulation still appears to support innovation, the reduced magnitude implies that uncoordinated or fragmented governance may dilute the overall effectiveness of renewable energy regulatory strategies. This result supports the hypothesis that uneven or inconsistent regulation at the regional level might diminish the innovation-enhancing effects of national regulations. Specifically, the interaction term is often collinear with national regulations, which could indicate that regional regulations may act as noise that potentially distorts otherwise beneficial impact of national regulation, or that they are produced in a manner that does not fully align with national goals which might diffuse a greater degree of regulatory fragmentation. This analysis highlights the importance of a cohesive regulatory framework that balances both national and regional efforts to foster green innovation.

The empirical results may be influenced by the distinct distribution of regulatory competencies between the national government and the regional governments. While the national level sets the overarching legal and economic framework, including retribution regimes such as subsidies and financial incentives, regional governments primarily exercise authority over land use, urban planning, and authorization of installations within their territory (Saggesse, 2010). These regional competencies often translate into spatial or procedural limitations rather than active enablers of innovation. Moreover, the diversity in how regional authorities interpret and implement their powers can result in fragmented or inconsistent regulatory environments.

It should be noted that the scope of omitted variable bias is small since the estimated effect of renewable energy regulation does not seem to be absorbed by overall labor supply, physical capital stock and overall labor productivity. An important channel arises from the potential fragmentation of regulation at the subnational level, highlighting diminishing returns as the elasticity of the combination of regulations captured by the interaction effect is smaller than that of national regulation on their own (See Table 2 and results above).

[17] Note that adding the interaction on top of national and regional regulation provides non-significant results due to the collinearity between interaction variable and national regulation. One possible explanation is that regional regulation is uneven, as opposed to national regulations, expressing variable lags in the transposition process at the regional level.

Furthermore, Table 3 presents the dynamic effect of increasing regulatory volume on innovation expenditure and employment of the regions (Autonomous Communities) across Spain. Compared to the static specifications in Table 2, this particular specification consists of the first lag of the national renewable energy regulation and its region-level counterpart, embedding partial adjustment mechanism into the relationship between renewable energy regulation and innovation dynamics. The evidence confirms our prior results. In this respect, the evidence shows that region-level renewable energy regulatory volume fails to translate into meaningful increases in innovation and R&D expenditures and R&D personnel as the estimated coefficient on the lagged region-level innovation variable is not statistically significantly different from zero across the full spectrum of specifications reported in columns (1) through (12) [-0.0208, 0.0244] ($p>0.1$). By contrast, the evidence indicates a positive and statistically significant impact of national regulation on R&D employment [0.0974, 0.0984] ($p<0.01$) and R&D expenditure indicators [0.107, 0.114] ($p<0.01$) that do not seem to be absorbed by the varying coefficients on factor input variables as well as overall productivity dynamics. Moreover, the evidence from our results further corroborates the notion that fragmentation of regulation appears to be an important stumbling block and impediment against more vibrant within and between-region innovation dynamics since the estimated parameter on the elasticity of the combined effect of regulation is smaller than the elasticity of the national regulation alone.

Table 2. Static effect of regulatory volume on region-level innovation dynamics across regions in Spain (OLS) (2008-2022)

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Variable	Ln(InnE)	Ln(InnE)	Ln(InnE)	Ln(InnE)	ln(RDE)	ln(RDE)	ln(RDE)	ln(RDE)	ln(RDPer)	ln(RDPer)	ln(RDPer)	ln(RDPer)
ln(RRenReg)	0.0429	0.0464			0.0195	0.0328			0.0128	0.0289		
	(0.0402)	(0.0326)			(0.0353)	(0.0302)			(0.0310)	(0.0274)		
ln(RRenNac)	0.117**	0.0780*			0.116***	0.134***			0.0799***	0.111***		
	(0.0466)	(0.0391)			(0.0294)	(0.0278)			(0.0244)	(0.0167)		
ln(RRenReg)# ln(RRenNac)			0.0226*	0.0185*			0.0206*	0.0238**			0.0141	0.0199**
			(0.013)	(0.010)			(0.0110)	(0.00919			(0.0096)	(0.0081)
Ln(K)	-0.0999	-0.107	-0.106	-0.108	-0.166	-0.185	-0.164	-0.177	-0.119	-0.142	-0.117	-0.135
	(0.191)	(0.172)	(0.187)	(0.169)	(0.185)	(0.181)	(0.185)	(0.180)	(0.131)	(0.133)	(0.132)	(0.134)
Ln(Employ)	1.664***	2.371***	1.678***	2.472***	1.618***	1.231*	1.643***	1.454**	1.402***	0.758	1.426***	0.942**
	(0.238)	(0.546)	(0.232)	(0.528)	(0.282)	(0.698)	(0.270)	(0.625)	(0.625)	(0.455)	(0.193)	(0.397)
Ln(GDP)	0.728***	0.317	0.676***	0.237	0.251	0.470	0.173	0.282	0.0770	0.437	0.0196	0.282
	(0.195)	(0.352)	(0.202)	(0.351)	(0.269)	(0.441)	(0.280)	(0.425)	(0.203)	(0.255)	(0.210)	(0.234)
LN(Prod)	1.661	2.497*	1.577	2.565*	3.633***	3.204*	3.614***	3.411**	3.338***	2.607***	3.334***	2.778**
	(1.023)	(1.250)	(0.973)	(1.219)	(1.022)	(1.520)	(0.985)	(0.733)	(0.733)	(1.050)	(0.709)	(0.957)
Fixed effects (FE) or Random Effects (RE)	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE
Intercept	-4.839	-9.729*	-3.867	-9.878*	-11.08***	-8.200	-10.50***	-9.055	-12.76***	-7.975	-12.42***	-8.683*
	(3.3788)	(5.406)	(3.499)	(5.360)	(3.516)	(6.366)	(3.387)	(5.848)	(1.608)	(2.001)	(3.078)	(4.305)
# observations	221	221	221	221	238	238	238	238	238	238	238	238
R^2	0.863	0.862	0.859	0.861	0.885	0.880	0.880	0.877	0.903	0.379	0.899	0.889
Wald – Test	211.14 (<0.0000)		183.50 (<0.0000)		177.11 (<0.0000)		164.32 (<0.0000)		181.64 (<0.0000)		180.36 (<0.0000)	
F-Test		F(6,16)=17.03 (0.0000)		F(5,16)=19.30 (0.0000)		F(6,16)=13.59 (0.0000)		F(5,16)=9.36 (0.0003)		F(6,16)=12.22 (0.0000)		F(5,16)=5.89 (0.0029)

Notes: the table presents the static effect of national-level, region-level and interactive regulatory volume (RRenNac and RRenReg, respectively) on private R&D expenditure across the full sample of autonomous communities in Spain for the period 2008-2022. Standard errors are adjusted for arbitrary heteroskedasticity and serially correlated stochastic disturbances using finite-sample adjustment of the empirical distribution function based on the composite two-way error component model. Cluster-robust standard errors are reported in the parentheses. Asterisks denote statistically significant sample coefficients at 10% (*), 5% (**), and 1% (***), respectively.

Table 3: Dynamic effect regulatory volume on region-level innovation dynamics across regions in Spain (OLS with lags) (2008-2022)

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Variable	Ln(InnE)	Ln(InnE)	Ln(InnE)	Ln(InnE)	ln(RDE)	ln(RDE)	ln(RDE)	ln(RDE)	ln(RDPer)	ln(RDPer)	ln(RDPer)	ln(RDPer)
L. ln(RRenReg)	0.0244	0.00931			-0.0109	-0.0101			-0.0276	-0.0208		
	(0.0391)	(0.0358)			(0.0353)	(0.0294)			(0.0308)	(0.0252)		
L. ln(RRenNac)	0.0168	-0.00340			0.114***	0.107***			0.0974***	0.0984***		
	(0.0340)	(0.0358)			(0.0246)	(0.0254)			(0.0240)	(0.0198)		
L. ln(RRenReg)# L. ln(RRenNac)			0.00796	0.00268			0.00995	0.00908			0.00441	0.00578
			(0.00892)	(0.00843)			(0.0102)	(0.00856)			(0.00918)	(0.00731)
Ln(K)	-0.0965	-0.107	-0.0964	-0.105	-0.151	-0.156	-0.142	-0.148	-0.129	-0.134	-0.121	-0.126
	(0.196)	(0.182)	(0.190)	(0.178)	(0.198)	(0.193)	(0.199)	(0.194)	(0.140)	(0.140)	(0.143)	(0.142)
Ln(Employ)	1.710***	2.917***	1.709***	2.910***	1.706***	1.962**	1.697***	2.010**	1.527***	1.458**	1.523***	1.505***
	(0.242)	(0.655)	(0.240)	(0.657)	(0.287)	(0.767)	(0.283)	(0.736)	(0.210)	(0.518)	(0.203)	(0.486)
Ln(Prod)	1.901**	2.963**	1.907*	3.002**	3.870***	4.086**	3.571***	3.853**	3.393***	3.342***	3.111***	3.111***
	(0.905)	(1.193)	(0.986)	(1.260)	(1.133)	(1.520)	(1.133)	(1.508)	(0.816)	(1.071)	(0.804)	(1.039)
Ln(GDP)	0.493**	-0.0772	0.491**	-0.0699	0.205	0.0912	0.0703	-0.0588	0.149	0.176	0.0182	0.0274
	(0.192)	(0.362)	(0.192)	(0.351)	(0.278)	(0.473)	(0.282)	(0.460)	(0.208)	(0.296)	(0.217)	(0.292)
Fixed effects (FE) or Random Effects (RE)	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE
Intercept	-4.734	-12.15**	-4.703	-12.36**	-12.49***	-14.01**	-10.29***	-12.31*	-13.73***	-13.25**	-11.68***	-11.59**
	(3.148)	(5.475)	(3.367)	(5.728)	(3.574)	(6.437)	(3.580)	(6.392)	(2.966)	(4.722)	(2.918)	(4.587)
#Observations	204	204	204	204	221	221	221	221	221	221	221	221
R^2	0.865	0.865	0.864	0.865	0.889	0.889	0.884	0.885	0.908	0.908	0.903	0.903
Wald – Test (p-value)	192.25 (0.0000)		191.56 (0.0000)		198.48 (0.0000)		181.36 (0.0000)		234.54 (0.0000)		215.40 (0.0000)	
F-Test (p-value)		F(6,16)=11.81 (0.0000)		F(5,16)=14.18 (0.0000)		F(6,16)=11.86 (0.0000)		F(5,16)=11.24 (0.0001)		F(6,16)=7.67 (0.0005)		F(5,16)=6.85 (0.0014)

Notes: the table presents the dynamic effect of national-level, region-level and interactive regulatory volume on private R&D expenditure across the full sample of autonomous communities in Spain for the period 2008-2022. Standard errors are adjusted for arbitrary heteroskedasticity and serially correlated stochastic disturbances using finite-sample adjustment of the empirical distribution function based on the composite two-way error component model. Cluster-robust standard errors are reported in the parentheses. Asterisks denote statistically significant sample coefficients at 10% (*), 5% (**), and 1% (***), respectively.

Additionally, Table 4 below reports a dynamic effect of renewable energy regulation on region-level innovation outcomes allowing for the endogeneity of regulation. More specifically, the table reports Arellano and Bond (1991) estimated dynamic specification of the region-level innovation model. By allowing for two lags of the dependent variable and one lag of the regulation variable, we are able to partially address the potential endogeneity of regulation and allow for dynamic realization of the regulatory effect on innovation outcomes. Our analysis proceeds in two distinctive steps. In the first step, we assess dynamic endogenous effect of regional renewable energy regulation on innovation whilst in the second step, the national counterpart of the regional renewable energy regulation is used to assess the effect with respect to regional innovation. Since our specification conveys a doubly dynamic past realization of the outcome and regulation, we also compute the cumulative effect of regulation through the simple Wald linear restriction of the effect of regulation in period t and t-1 relative to the past realization of the innovation outcome in period t and t-1. The use of linear restriction of coefficient ratio is particularly informative and allows us to determine whether the effect of regulation either fades away or amplifies itself once past outcome dynamics is considered.

Columns (1) and (2) report the effect of regional and national regulation on expenditure level. The evidence suggests that each additional norm on renewable energy at the regional level fails to boost R&D expenditure. At the same time, we find no evidence of discernible negative and significant effect. The cumulative effect of regional regulation after two years seems to be weak and statistically indistinguishable from zero (i.e. p-value = 0.48). In column (2), the point estimates indicate no static effect of increasing national regulatory volume on renewable energy on innovation dynamics. However, the coefficient on the past regulatory volume is both negative and statistically significant at 5%, indicating that 1 percent increase in the regulatory volume tends to dampen R&D expenditure, on average, by 0.18 percent, respectively. However, the cumulative effect after two years is not statistically significantly different from zero (i.e. p-value = 0.45) and suggests that the expansion of regulatory norms mimics the characteristics of the negative but temporary short-term shock to innovation expenditure. Columns (3) and (4) presents the effect of renewable energy regulation on private-sector expenditure on R&D. The evidence indicates a mixed effect with respect to the expenditure. Point estimates in column (3) unequivocally show that increasing regulation is associated with a marked drop in commercial expenditure on innovation. By way of example, our estimates show that 1 percent increase in renewable energy regional regulation in period t-1 is associated with 0.02 percent drop in private-sector innovation expenditure, *ceteris paribus*. Since the static effect of regional regulation in period t is not statistically significantly different from zero, the question that remains is whether the cumulative effect after two years is either positive or null. By computing the Wald linear restriction, we show that after two years, the cumulative effect of regional renewable energy regulation volume on private-sector expenditure is both negative and statistically significant at 10%. In particular, the cumulative effect of 1 percent increase in regional renewable energy regulatory volume is associated with around 0.1 percent drop in private-sector R&D expenditure (i.e. p-value = 0.065). It should be noted that the estimated effect does not depend on the past realization of the expenditure itself and is not absorbed by the standard confounding effects of the variation in the factor input variables in the production function. On the other hand, our estimates uncover the evidence of the positive and statistically significant effect of national regulation on renewable energy on private-sector expenditure. Substantial and significant positive effect is not characterized by an immediate, static realization but instead with a dynamic realization after one year. The cumulative effect of 1 percent increase in renewable energy regulation appears to be around 0.13 percent increase in R&D expenditure levels, respectively (i.e. p-value = 0.007). On balance, our evidence shows some support for the notion that whilst national regulation on renewable energy tends to enhance and boost private-sector R&D expenditure, an equivalent and comparable increase in the volume of renewable energy regulation at the region level has an opposite effect and tends to depress innovation expenditure significantly. This is consistent with the evidence in Table 2, and suggests that support schemes at the national level are a source of increase in private sector innovation and R&D expenditure whilst cumulatively [0.0124] ($p<0.01$), to no avail, failing to pinpoint region-level regulation as a source of expenditure boost. Furthermore, estimates in column (6) indicate positive overall effect of national regulatory volume on R&D employment, with cumulative effects of regulation positive and statistically significant [0.362] ($p<0.01$) in contrast to null effect of regional regulatory volume in column (5).

To sum up, dynamic results, from Table 4, offer evidence regarding the hypotheses outlined in Section 2. In regards to H1, the results indicate that national renewable energy regulations exert a positive and statistically significant effect on firm-level innovation, as reflected in metrics such as R&D expenditure and employment partially supporting H1 in the longer run. Conversely, regional-level regulations fail to demonstrate a significant independent impact, suggesting their limited effectiveness in driving innovation in isolation.

Table 4. Dynamic endogenous effect of regulatory volume on region-level innovation dynamics across regions in Spain, 2008-2022

	Ln(InnE)		Ln(RDE)		Ln(RDPer)	
Exposure variable	Regional	National	Regional	National	Regional	National
Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Ln(Y)(t-1)	0.416*** (.171)	0.396** (.170)	0.714*** (.065)	0.707*** (.067)	0.670*** (.090)	0.658 (.077)
Ln(Y) (t-2)	0.269*** (.091)	0.286*** (.095)	0.028 (.064)	0.057 (.062)	0.129* (.075)	0.173 (.065)
RRen (t)	0.022 (.020)	0.007 (.054)	-0.004 (.005)	0.128*** (.021)	0.017 (.015)	0.139*** (.023)
RRen(t-1)	0.0008 (.031)	-0.184** (.087)	-0.020** (.010)	-0.099*** (.021)	-0.028** (.013)	-0.078*** (.017)
Wald Linear Restriction on Cumulative Effect	0.072 (.048)	-0.555 (.736)	-0.096* (.052)	0.124*** (.045)	-0.053 (.105)	0.362*** (.128)
Wald p-value	0.48	0.45	0.065	0.007	0.613	0.005
Structural controls (p-value)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)
Time-fixed effects (p-value)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)
Region-fixed effect (p-value)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)	YES (0.000)
Wu-Hausman Endogeneity Test of Regulation (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
# lags of dependent variables	2	2	2	2	2	2
# lags of endogenous variable	1	1	1	1	1	1
# observations	187	187	204	204	204	204
Wald test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000

Source: Own elaboration.

Notes: the table reports the effect of national and regional regulatory volume on renewable energy sources on public and private expenditure on R&D and R&D employment across and within regions (Autonomous Communities) in Spain for the period 2008-2022 using Arellano-Bond dynamic estimator. The cumulative interaction effect after two years is computed using non-linear Wald restriction of the ratio between current and lagged regulation variables and current and lagged outcome variables. Standard errors are adjusted for serially correlated stochastic disturbances and arbitrary heteroskedasticity using finite-sample adjustment of the empirical distribution function and non-nested region-level clustering scheme. Cluster-robust standard errors are reported in the parentheses. Asterisks denote statistically significant panel-level coefficients at 10 % (*), 5% (**), and 1% (***), respectively.

In Table 5, we estimate a dynamic interaction effect between regional and national regulation on renewable energy on public and private expenditure on R&D as well as R&D employment. The evidence suggests that the combined effect of regional and national regulatory volume on innovation expenditure and R&D employment is mixed. For instance, point estimates in column (1) indicate a positive interaction effect of regional and national regulation on public innovation expenditure. The positive effect is immediate and indicates about 0.076 percent expenditure boost from 1 percent increase in the joint regulatory volume, *ceteris paribus*. Yet, the effect seems to fizzle out after one year as the cumulative interaction effect is not statistically significantly different from zero (i.e. p-value = 0.368), suggesting that the positive interaction effect is temporary at best and does not yield sustained increases in firms expenditure on innovation. In column (2), we estimate the equivalent interaction effect of regulatory volume on private-sector R&D expenditure. We find that no evidence of the instantaneous increase in expenditure in response to the joint increase in the regulatory volume whilst the coefficient on the lagged interaction effect is negative and statistically significant, indicating a short-term, temporary distortive effect of the interaction between national and regional renewable energy regulation on private-sector expenditure. The cumulative interaction effect is not statistically significant different from zero, and rules out lasting and permanent deterioration in private-sector expenditure in response to the expansion of regulatory volume through legal norms. We find similar evidence of the interaction effect between regional and national regulation on R&D employment. The evidence highlights negative and statistically significant lagged effect of the interaction term between national and regulation region whereas the cumulative effect after two years is not statistically different from zero (i.e. p-value = 0.603). Our estimates in Table 5 convey an important normative implication for the policymaker. Since the separate effect of the number of national regulations on Innovation, R&D expenditure and R&D employment in firms is positive and statistically significant at conventional levels, the interaction of national and regional regulation on renewable energies yields both temporary negative effect and no discernible long-term effect on both expenditure and R&D employment. Without the loss of generality, this particular distinction emanating from our results indicate a negative non-synergetic feedback loop between the number of regional and national regulation on renewable energy where the former tends to displace the positive effect of the latter with respect to both employment and expenditure. The displacive effect of regional regulation over the national regulation of renewable energies could be related to the idea that the fragmentation of regulation could be a non-trivial policy distortion that may transmit similar kind of negative effect as the increasing and excessive volume of regulation.

In this case, the interaction between national and regional regulations exhibits a positive, albeit modest, effect on innovation outcomes, highlighting the potential benefits of regulatory alignment in line with the results of our baseline analysis in Table 2. A non-significant direct effect of regional regulation, together with a weak positive interaction with national regulation provide evidence that regional regulation is useful insofar it is consistent with national regulation. However, it falls short on concluding that the increase of regional regulation has a negative effect. Indeed, although the coexistence of both regulatory levels continues to promote innovation to some extent, the attenuated effects suggest that misaligned approaches could undermine the full potential of renewable energy policy framework.

Our analysis provides additional impetus to further analysis in the future research by opening several questions behind the tentative conclusions. For instance, the sign of the interaction effect between different layers of regulation may highlight a reasonably strong degree of regulatory fragmentation as a source of transaction costs that hinders a better and faster coordination and bends directly on the innovation expenditure. In this respect, a positive interaction term may partially indicate whether the positive effect of national regulation is offset by the fragmented structure of the regulation since the region-level regulation fails to generate additional firm-level expenditure on R&D. In this perspective, future research would investigate whether national and regional regulations are fragmented (increase at different speed across regions) or contradictory across jurisdiction levels, and may address its roots and consequences to better understand its spread across space and time.

These preliminary findings underscore the critical role of regulatory coherence and coordination in fostering firm innovation within complex multi-level governance frameworks, explaining why H2 is not supported by the data.

Table 5: Endogenous interaction effect of regulatory volume on region-level innovation dynamics across regions in Spain, 2008-2022

Model	**(1)**	**(2)**	**(3)**
	Ln(InnE)	Ln(RDE)	Ln(RDPer)
Ln(Y)(t-1)	0.404**	0.718***	0.672***
	(.168)	(.065)	(.088)
Ln(Y) (t-2)	0.277***	0.024	0.123*
	(.092)	(.065)	(.074)
(RRenNac × RRenRegt	0.076*	0.005	0.018
	(.045)	(.011)	(.018)
(RRenNac × RRenReg) (t-1)	-0.002	-0.006**	-0.009**
	(.009)	(.003)	(.003)
Cumulative Interaction Effect	0.231	-0.001	0.045
	(.257)	(.045)	(.087)
Wald Linear Restriction on Cumulative Effect (p-value)	0.368	0.968	0.603
Structural controls	YES	YES	YES
(p-value)	(0.000)	(0.000)	(0.000)
Time-fixed effects	YES	YES	YES
(p-value)	(0.000)	(0.000)	(0.000)
Region-fixed effect	YES	YES	YES
(p-value)	(0.000)	(0.000)	(0.000)
Wu-Hausman Endogeneity Test of Regulation (p-value)	0.000	0.000	0.000
# lags of dependent variables	2	2	2
# observations	204	204	204
Wald test (p-value)	0.000	0.000	0.000

Source: Own elaboration.
Notes: the table reports the interaction effect between national and regional regulatory volume of renewable energy sources on public and private expenditure on R&D and R&D employment across and within regions (Autonomous Communities) in Spain for the period 2008-2022 using Arellano-Bond dynamic estimator. The cumulative interaction effect after two years is computed using non-linear Wald restriction of the ratio between current and lagged regulation variables and current and lagged outcome variables. Standard errors are adjusted for serially correlated stochastic disturbances and arbitrary heteroskedasticity using finite-sample adjustment of the empirical distribution function and non-nested region-level clustering scheme. Cluster-robust standard errors are reported in the parentheses. Asterisks denote statistically significant panel-level coefficients at 10 % (*), 5% (**), and 1% (***), respectively.

5. Conclusions

In this paper, we empirically analyze whether "green regulation", in particular renewable energies regulation, and its volume generate a positive or negative impact on firm innovation. To this end, we rely on a regulatory database (Mora-Sanguinetti and Atienza-Maeso, 2024a) for all Spanish regions (Autonomous Communities) as well as at the national level, for the period 2008-2022, which identifies and classifies the regulations of interest related to renewable energies and other "green" subjects. Through the lens of the descriptive analysis we show that the volume of regulation tends to increase over time although the pace and trend of the increase is not uniform across regions. In the subsequent step, we empirically operationalize the Cobb-Douglas production function with endogenous technological progress allowing for partial adjustment of the technology level to the dynamic changes in innovation.

The empirical evidence for Spain suggests that a more vibrant and increasing volume of regulation on renewable energy does not translate into discernible dampening effect on the variety of innovation indicators such as expenditure on innovation, R&D expenditure and R&D employment. On the contrary, we find evidence of a positive effect of “green regulation” on the innovation dynamics under an intricate mechanism. By decomposing the regulation into its national and regional components, we show that the former is associated with a more vibrant innovation dynamics whilst the latter is not and cannot be distinguished from zero at conventional levels of statistical significance. By looking at the interaction effect between national and regional regulation, the positive and statistically significant, but attenuated, effect in comparison to the isolate impact of national regulation, suggests a potential diminishing marginal return when combining different levels of regulation in Spain. The reduced magnitude of the effect in the innovation metrics at the firm level may imply that uncoordinated or fragmented governance could dilute the overall effectiveness of renewable energy regulatory strategies.. The exploration of this point can be pursued further by analysing in more detail which specific competences fall under national law and which specific competences fall under regional law. Yet, this would be a point to be explored in future research.

Our contribution to the literature adds an important and policy-relevant angle to the debate on the design of “better regulation” policies. Regulation in these matters would be more effective if it is characterized by a lower degree of fragmentation [on “better regulation” policies, see, e.g., European Commission (2015)]. A less fragmented and more streamlined regulation on “green” issues (such as renewable energy regulation) differs significantly from the classical view of regulation as a binding constraint on the process of creative destruction and growth. More specifically, we suggest that the transition towards net-zero emissions that has been underpinned by the European Union for the foreseeable future may need a greater degree of centralization, with more clearly aligned support schemes, avoiding complex regulatory structures. While we do not provide a measure of fragmentation in this study; the results based on the volume of regulation at different jurisdictional level, seems to confirm that a more fragmented regulatory regime in a (similar to a) federal environment such as the one that characterizes the Spanish case may be unfriendly to the process of innovation at the firm level.

A possible extension of the analysis for the Spanish case could be to explore how other legal innovations reach the market, for example, through the work of Spanish judges interpreting the adopted norms.

References

Acemoglu, Daron, and Pascual Restrepo. (2019). “Automation and new tasks: How technology displaces and reinstates labor”. *Journal of Economic Perspectives*, 33(2), pp, 3-30. https://doi.org/10.1257/jep.33.2.3

Aghion, Philippe, and Peter Howitt. (1992). «A model of growth through creative destruction». *Econometrica*, 60(2), pp. 323-351. https://doi.org/10.2307/2951599

Aghion, Philippe, and Peter Howitt. (2023). “The Creative Destruction Approach to Growth Economics”. *European Review*, 31(4), pp. 312-325. https://doi.org/10.1017/S1062798723000212

Albrizio, Silvia, Kozluk Tomasz and Vera Zipperer. (2017). “Environmental policies and productivity growth: Evidence across industries and firms”. *Journal of Environmental Economics and Management*, 81, pp. 209-226. https://doi.org/10.1016/j.jeem.2016.06.002

Alvarez, Javier, and Manuel Arellano. (2003). “The time series and cross-section asymptotics of dynamic panel data estimators”. *Econometrica*, 71(4), pp. 1121-1159. https://doi.org/10.1111/1468-0262.00441

Ardagna, Silvia, and Annamaria Lusardi. (2010). “1 - Explaining international differences in entrepreneurship: The role of individual characteristics and regulatory constraints”. In Josh Lerner and Antoinette Schoar (eds.), *International differences in entrepreneurship. University of Chicago Press*, pp. 17-62. https://doi.org/10.7208/chicago/9780226473109.003.0002

Arellano, Manuel and Stephen Bond. (1991). “Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations”. *The Review of Economic Studies*, 58(2), pp. 277-297. https://doi.org/10.2307/2297968

Ashford, Nicholas A., and Ralph P. Hall. (2011). *Technology, Globalization, and Sustainable Development: Transforming the Industrial State.* Yale University Press.

Bacigalupo Saggese, Mariano. (2010). “La distribución de competencias entre el Estado y las Comunidades Autónomas en materia de energías renovables». *Revista d’Estudis Autonòmics iFfederals*, 10(4), pp. 286-329. https://hdl.handle.net/20.500.14623/1491

Bardhan, Pranab. (2002). “Decentralization of governance and development”. *Journal of Economic Perspectives*, 16(4), pp. 185-205. https://doi.org/10.1257/089533002320951037

Becker, Gary S., and Kevin M. Murphy. (1992). “The division of labor, coordination costs, and knowledge”. *The Quarterly Journal of Economics*, 107(4), pp. 1137-1160. https://doi.org/10.2307/2118383

Blind, Knut. (2012). “The influence of regulations on innovation: A quantitative assessment for OECD countries”. *Research Policy*, 41(2), pp. 391-400. https://doi.org/10.1016/j.respol.2011.08.008

Borrás, Susana, and Jakob Edler (eds.). (2014). *The Governance of Socio-Technical Systems: Explaining Change.* Edward Elgar Publishing. https://doi.org/10.4337/9781784710194

Burtraw, Dallas, and David A. Evans. (2009). “Tradable Rights to Emit Air Pollution”. *Australian Journal of Agricultural and Resource Economics*, 53(1), pp. 59-84 https://doi.org/10.1111/j.1467-8489.2007.00428.x

Cainelli, Giulio, Massimiliano Mazzanti and Sandro Montresor. (2012). “Environmental innovations, local networks and internationalization”. *Industry and Innovation*, 19(8), pp. 697-734. https://doi.org/10.1080/13662716.2012.739782

Carrillo-Hermosilla, Javier, Pablo Del Río and Totti Könnölä. (2009). *Eco-innovation: When sustainability and competitiveness shake hands.* Palgrave Macmillan. https://doi.org/10.1057/9780230244856

Cecere, Grazia, Nicoletta Corrocher, Cédric Gossart and Muge Ozman. (2014). "Lock-in and path dependence: an evolutionary approach to eco-innovations". *Journal of Evolutionary Economics,* 24, pp. 1037-1065. https://doi.org/10.1007/s00191-014-0381-5

Cobb, Charles W., and Paul H. Douglas. (1928). "A Theory of Production". *The American Economic Review,* 18(1), pp. 139-165. https://www.jstor.org/stable/1811556

Crépon, Bruno, Emmanuel Duguet and Jacques Mairesse. (1998). "Research, innovation, and productivity: An econometric analysis at the firm level". *Economics of Innovation and New Technology,* 7(2), pp. 115-158. https://doi.org/10.1080/10438599800000031

Dawson, John W., and John J. Seater. (2013). "Federal regulation and aggregate economic growth". *Journal of Economic Growth,* 18, pp. 137-177. https://doi.org/10.1007/s10887-013-9088-y

De Lucio, Juan, and Juan S. Mora-Sanguinetti. (2022). "Drafting 'better regulation': the economic cost of regulatory complexity". *Journal of Policy Modeling,* 44(1), pp. 163-183. https://doi.org/10.1016/j.jpolmod.2021.10.003

De Marchi, Valentina. (2012). "Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms". *Research Policy,* 41(3), pp. 614-623. https://doi.org/10.1016/j.respol.2011.10.002

Del Río, Pablo. (2009). "The empirical analysis of the determinants for environmental technological change: A research agenda". *Ecological Economics,* 68(3), pp. 861-878. https://doi.org/10.1016/j.ecolecon.2008.07.004

Del Río, Pablo, Cristina Peñasco and Desiderio Romero-Jordán. (2015). "Distinctive features of environmental innovators: An econometric analysis". *Business Strategy and the Environment,* 24(6), pp. 361-385. https://doi.org/10.1002/bse.1822

Del Río, Pablo, Cristina Peñasco and Desiderio Romero-Jordán. (2016). "What drives eco-innovators? A critical review of the empirical literature based on econometric methods". *Journal of Cleaner Production,* 153, pp. 278-288. https://doi.org/10.1016/j.jclepro.2015.09.009

Di Vita, Giuseppe. (2018). "Institutional quality and the growth rates of the Italian regions: The costs of regulatory complexity". *Papers in Regional Science,* 97(4), pp. 1057-1081. https://doi.org/10.1111/pirs.12290

Draghi, Mario. (2024). "Part A - A competitiveness strategy for Europe". In European Commission, *The future of European competitiveness.* https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en

Ellingsen, Tore. (1998). "Externalities vs internalities: A model of political integration". *Journal of Public Economics,* 68(2), pp. 251-268. https://doi.org/10.1016/S0047-2727(97)00090-X

European Commission. (2015). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Better regulation for better results - An EU agenda.* Strasbourg, May 19th, COM (2015) 215 final. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0215

Flanagan, Kieron, Elvira Uyarra and Manuel Laranja. (2011). "Reconceptualising the 'policy mix' for innovation". *Research Policy*, 40(5), pp. 702-713. https://doi.org/10.1016/j.respol.2011.02.005

García-Posada, Miguel, and Juan S. Mora-Sanguinetti. (2014). "Entrepreneurship and Enforcement Institutions: Disaggregated Evidence for Spain". *European Journal of Law and Economics*, 40(1), pp. 49-74. https://repositorio.bde.es/handle/123456789/7091

Ghisetti, Claudia, and Sandro Montresor. (2020). "On the adoption of circular economy practices by small and medium-size enterprises (SMEs): does "financing-as-usual» still matter?". *Journal of Evolutionary Economics*, 30, pp. 559-586. https://doi.org/10.1007/s00191-019-00651-w

Ghisetti, Claudia, and Francesco Quatraro. (2017). "Green technologies and environmental productivity: A cross-sectoral analysis of direct and indirect effects in Italian regions". *Ecological Economics*, 132, pp. 1-13. https://doi.org/10.1016/j.ecolecon.2016.10.003

Goulder, Lawrence H., and Robert N. Stavins. (2011). "Challenges from state-federal interactions in US climate change policy". *American Economic Review*, 101(3), pp. 253-257. https://doi.org/10.1257/aer.101.3.253

Grubb, Michael, Paul Drummond, Jean-Francois Mercure, Cameron Hepburn, Peter Barbrook-Johnson, João Carlos Ferraz, Alex Clark, Laura Diaz Anadon, Doyne Farmer, Ben Hinder, Matt Ives, Aled Jones, Gao Jun, Ulka Kelkar, Sergey Kolesnikov, Aileen Lam, Ritu Mathur, Roberto Pasqualino, Cristina Penasco, Hector Pollitt, Luma Ramos, Andrea Roventini, Pablo Salas, Simon Sharpe, Zhu Songli, Pim Vercoulen, Kamna Waghray and Zhang Xiliang. (2021b). *The new economics of innovation and transition: Evaluating opportunities and risks.* The Economics of Energy Innovation and System Transition (EEIST) Consortium. https://eeist.co.uk/eeist-reports/the-new-economics-of-innovation-and-transition-evaluating-opportunities-and-risks/#

Grubb, Michael, Paul Drummond, Alexandra Poncia, Will McDowall, David Popp, Sascha Samadi, Cristina Penasco, Kenneth T Gillingham, Sjak Smulders, Matthieu Glachant, Gavin Hassall, Emi Mizuno, Edward S. Rubin, Antoine Dechezleprêtre and Giulia Pavan. (2021a). "Induced innovation in energy technologies and systems: a review of evidence and potential implications for CO2 mitigation". *Environmental Research Letters*, 16(4/043007). https://doi.org/10.1088/1748-9326/abde07

Grubler, Arnulf, Francisco Aguayo, Kelly S. Gallagher, Marko Hekkert, Kejun Jiang, Lynn Mytelka, Lena Neij, Gregory Nemet, Charlie Wilson, Per Dannemand Andersen, Leon Clarke, Laura Diaz Anadon, Sabine Fuss, Martin Jakob, Daniel Kammen, Ruud Kempener, Osamu Kimura, Bernadette Kiss, Anastasia O'Rourke, Robert N. Schock, Paulo Teixeira de Sousa Jr. and Leena Srivastava. (2012). "Chapter 24 - Policies for the energy technology innovation system (ETIS)". In Thomas B. Johansson, Nebojsa Nakicenovic, Anand Patwardhan and Luis Gomez-Echeverri (eds.), *Global Energy Assessment: Toward a Sustainable Future.* Cambridge University Press, pp. 1665-1744. https://doi.org/10.1017/CBO9780511793677.030

Havik, Karel, Kieran Mc Morrow, Werner Röger and Alessandro Turrini. (2008). "The EU-US total factor productivity gap: An industry perspective". European Economy - Economic Papers, 339, Directorate General Economic and Monetary Affairs - European Commission. https://ec.europa.eu/economy_finance/publications/pages/publication13143_en.pdf

Hooghe, Liesbet, Arjan H. Schakel and Gary Marks. (2008). "Supporting Information Appendix B: Country and regional scores". *Regional & Federal Studies*, 18(2-3), pp. 259-274. https://doi.org/10.1080/13597560801994331

Horbach, J., Rammer, C., and K. Rennings. (2012). "Determinants of eco-innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull". *Ecological Economics,* 78, pp. 112-122. https://doi.org/10.1016/j.ecolecon.2012.04.005

Kivimaa, Paula, and Florian Kern. (2016). "Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions". *Research Policy,* 45(1), pp. 205-217. https://doi.org/10.1016/j.respol.2015.09.008

Laeven, Luc, and Chistopher Woodruff. (2007). "The quality of the legal system, firm ownership, and firm size". *The Review of Economics and Statistics,* 89(4), pp. 601-614. https://doi.org/10.1162/rest.89.4.601

Lach, Saul. (2002). "Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel". *The Journal of Industrial Economics,* 50(4), pp. 369-390. https://doi.org/10.1111/1467-6451.00182

Lehmann, Paul, and Erik Gawel. (2013). "Why Should Support Schemes for Renewable Electricity Complement the EU Emissions Trading Scheme?". *Energy Policy,* 52, pp. 597-607. https://doi.org/10.1016/j.enpol.2012.10.018

Lo, Kevin. (2015). "China's Low-Carbon City Initiatives: The Implementation Gap and the Limits of the Target Responsibility System". *Habitat International,* 42, pp. 236-244. https://doi.org/10.1016/j.habitatint.2014.01.007

López Guerra, Luis, Eduardo Espín, Joaquín García Morillo, Pablo Pérez Tremps and Miguel Satrústegui. (2018). *Derecho Constitucional Volumen II* (11.ª ed.). Tirant Lo Blanch.

McLaughlin, Patrick A., Oliver Sherouse, Daniel Francis, Jonathan Nelson, Thurston Powers, Walter Stover and James Broughel. (2019). *State RegData, QuantGov.* Mercatus Center, George Mason University.

McMorrow, Kieran, and Werner Röger. (2009). "R&D capital and economic growth: The empirical evidence". EIB Papers, 14(1), European Investment Bank, pp. 94-118. https://hdl.handle.net/10419/44909

Mora-Sanguinetti, Juan S. (2019). "La 'complejidad' de la regulación española ¿Cómo medirla? ¿Qué impacto económico tiene?". *Revista de Economía ICE,* 907 (Marzo-Abril 2019). pp. 147-162. https://doi.org/10.32796/ice.2019.907.6784

Mora-Sanguinetti, Juan S., and Andrés Atienza-Maeso. (2024a). "'Green Regulation': A Quantification of Regulations Related to Renewable Energies and Climate Change in Spain and France". Working Paper, 937, Banque de France. https://doi.org/10.2139/ssrn.4958856

Mora-Sanguinetti, Juan S., and Andrés Atienza-Maeso. (2024b). "How effective is equality regulation in reducing gender gaps in the labor market?". Journal of Policy Modeling. 46(5), pp. 823-846. https://doi.org/10.1016/j.jpolmod.2024.05.003

Mora-Sanguinetti, Juan S., and Ricardo Pérez-Valls. (2021). "How does regulatory complexity affect business demography? Evidence from Spain". *European Journal of Law and Economics,* 51, pp. 203-242. https://doi.org/10.1007/s10657-020-09650-w

Mora-Sanguinetti, Juan S., Javier Quintana, Isabel Soler and Rok Spruk. (2024). "The heterogenous effects of a higher volume of regulation: evidence from more than 200k Spanish norms". *Journal of Regulatory Economics,* 65, pp. 137-153. https://doi.org/10.1007/s11149-023-09466-x

Mora-Sanguinetti, Juan S., and Rok Spruk. (2023). "Economic Effects of Recent Experiences of Federalism: Analysis of the Regionalization Process in Spain". *Journal of Regional Science,* 63(1). pp. 30-63. https://doi.org/10.1111/jors.12616

Mustapha, Nik Hashim N., Nik Mohd H. Hashim and Ridzuam Yacob. (2013). "Technical components of total factor productivity growth in Malaysian manufacturing industry". *Applied Mathematics,* 4(9), pp. 1251-1259. https://doi.org/10.4236/am.2013.49169

North, Douglas C. (1981). *Structure and Change in Economic History.* Norton.

North, Douglas C. (1990). *Institutions, Institutional Change and Economic Performance.* Cambridge University Press. https://doi.org/10.1017/CBO9780511808678

North, Douglas C. (1999). "Understanding the process of economic change". Occasional Paper, 106, Institute of Economic Affairs. https://iea.org.uk/wp-content/uploads/2016/07/upldbook112pdf.pdf

OECD. (2009). *Sustainable manufacturing and eco-innovation. Framework, practices and measurement.* Synthesis report. Organisation for Economic Co-operation and Development. https://one.oecd.org/document/DSTI/IND(2009)5/en/pdf

OECD/Eurostat. (2018). *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation. The Measurement of Scientific, Technological and Innovation Activities. 4th Edition.* OECD Publishing. https://www.oecd.org/content/dam/oecd/en/publications/reports/2018/10/oslo-manual-2018_g1g9373b/9789264304604-en.pdf

Peñasco, Cristina, Laura Díaz Anadón and Elena Verdolini. (2021). "Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments". *Nature Climate Change,* 11, pp. 257-265. https://doi.org/10.1038/s41558-020-00971-x

Porter, Michael E., and Claas van der Linde. (1995). "Toward a New Conception of the Environment-Competitiveness Relationship". *Journal of Economic Perspectives,* 9(4), pp. 97-118. https://doi.org/10.1257/jep.9.4.97

Qiu, Lan, Zi-Ya Chen,Deng-Yu Lu, Hao Hu and Yi-Tao Wang. (2014). "Public funding and private investment for R&D: a survey in China's pharmaceutical industry". *Health Research Policy and Systems,* 12, 27. https://doi.org/10.1186/1478-4505-12-27

Ravšelj, Dejan, and Aleksander Aristovnik. (2018) "The impact of private research and development expenditures and tax incentives on sustainable corporate growth in selected OECD countries". *Sustainability,* 10(7/2304). https://doi.org/10.3390/su10072304

Rehman, Naqeeb U., Eglantina Hysa and Xuxin Mao. (2020). "Does public R&D complement or crowd-out private R&D in pre and post economic crisis of 2008?". *Journal of Applied Economics,* 23(1), pp. 349-371. https://doi.org/10.1080/15140326.2020.1762341

Rennings, Klaus. (2000). "Redefining innovation — eco-innovation research and the contribution from ecological economics". *Ecological economics,* 32(2), pp. 319-332. https://doi.org/10.1016/S0921-8009(99)00112-3

Rennings, Klaus, and Christian Rammer. (2011). "The impact of regulation-driven environmental innovation on innovation success and firm performance". *Industry and Innovation,* 18(3), pp. 255-283. https://doi.org/10.1080/13662716.2011.561027

Rogge, Karoline S., and Kristin Reichardt. (2016). "Policy mixes for sustainability transitions: An extended concept and framework for analysis". *Research Policy*, 45(8), pp. 1620-1635. https://doi.org/10.1016/j.respol.2016.04.004

Schumpeter, Joseph A. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Harvard University Press.

Schumpeter, Joseph A. (1942). *Capitalism, Socialism, and Democracy*. Harper & Brothers.

Schumpeter, Joseph A. (1947). "The Creative Response in Economic History". *The Journal of Economic History*, 7(2), pp. 149-159. https://doi.org/10.1017/S0022050700054279

UNFCCC. (2015). *Adoption of the Paris Agreement*. COP21, Paris, November. https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

Veugelers, Reinhilde. (2012). "Which Policy Instruments to Induce Clean Innovating?". *Research Policy*, 41(10), pp. 1770-1778. https://doi.org/10.1016/j.respol.2012.06.012

Vogel, David. (1995). *Trading Up: Consumer and Environmental Regulation in a Global Economy*. Harvard University Press.

World Bank. (2023). *Global Economic Prospects*. June 2023. World Bank Group. https://doi.org/10.1596/978-1-4648-1951-3

Wu, You-Qun, Jie Li and Jin-Chao Ma. (2022). "The Effect of Innovation Investment on Environmental Total Factor Productivity". *Mathematical Problems in Engineering*, 2022(1/3100174). https://doi.org/10.1155/2022/3100174

Zárate-Marco, Anabel, and Jaime Vallés-Jiménez. (2012). "The cost of regulation in a decentralized context: The case of the Spanish regions". *European Journal of Law and Economics*, 33(1), pp. 185-203. https://doi.org/10.1007/s10657-010-9154-2

Zeng, Meng, Lihang Liu, Fangyi Zhou and Yigui Xiao. (2021). "How does environmental regulation affect the relationship between FDI and technological innovation: From the perspective of technology transactions". *Processes*, 9(8/1264). https://doi.org/10.3390/pr9081264

Appendix

Table A1. Summary of the regulatory database ("Green regulations" by subject, 2000-2022)

SUBJECT	SPECIFIC TOPIC	AUTONOMOUS REGIONS	STATE (CENTRAL GOVERNMENT) NORMS
Renewable energies (*Energías renovables*)	Wind energy (*Energía eólica*)	204	46
	Solar energy (*Energía solar)*	313	66
	Renewable energy (general concept) *[Energía renovable (concepto)*]	2707	535
	Hydrogen (*Hidrógeno*)	32	39
	Total (Renewable energies) *[Total (energías renovables)]*	2876	606
Sustainable transportation *(Transporte sostenible)*	Electric vehicles (*vehículo eléctrico*)	514	214
	Low emission zones (*zonas de bajas emisiones*)	23	19
	Charging points (*puntos de recarga*)	310	68
	Sustainable transportation (total) [*transporte sostenible (total)*]	548	235
Pollution (*Contaminación*)	Pollution (*contaminación*)	70	38
Energy efficiency (*Eficiencia energética*)	Energy efficiency (concept) *["Eficiencia energética" (concepto)*]	3694	761
	Energy rating (*calificación energética*)	487	69

	Enegy efficiency (total) [*Eficiencia energética (total)*]	4281	835

Source: Mora-Sanguinetti and Atienza-Maeso (2024a).
Note: The database includes the year 2000 and then 2008-2022.

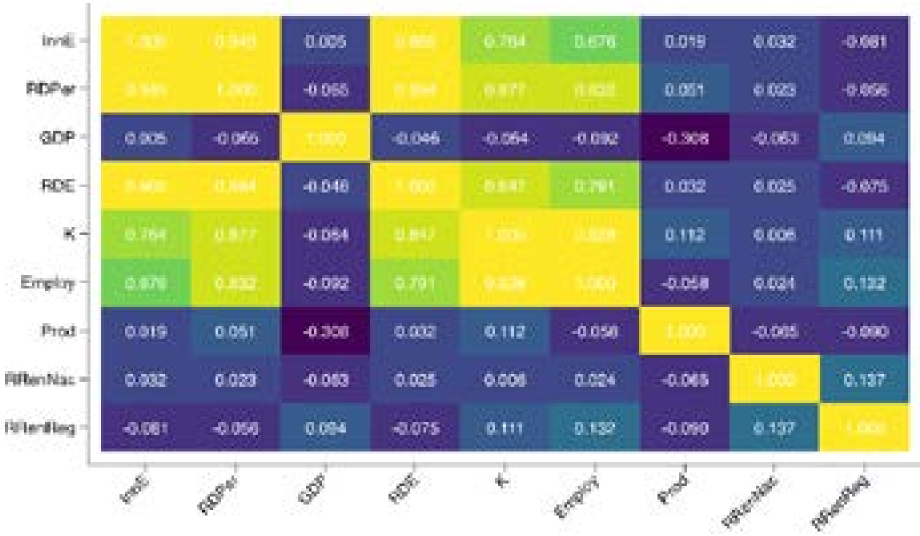
Table A2. Descriptive statistics of the regulatory database

Variable	**Panel dimension *(16 years of data X 17 regions = 272)***	**Mean**	**Std. dev.**	**Minimum number of norms found**	**Maximum number of norms found**
Wind energy (*Energía eólica*)	272	0,7500000	0,9888679	0	5
Solar energy (*Energía solar)*	272	1,1433820	1,5740140	0	9
Renewable energy (general concept) *[Energía renovable (concepto)*]	272	9,9264710	6,3352030	0	42
Hydrogen (*Hidrógeno*)	272	0,1176471	0,6020730	0	8
Total (Renewable energies) *[Total (energías renovables)]*	272	10,5441200	6,6364390	0	47
Electric vehicles (*vehículo eléctrico*)	272	1,8566180	2,5939240	0	16
Low emission zones (*zonas de bajas emisiones*)	272	0,0808824	0,3339387	0	2
Charging points (*puntos de recarga*)	272	1,1286760	1,8147570	0	13
Sustainable transportation (total) [*transporte sostenible (total)*]	272	1,9779410	2,7260310	0	16
Pollution (*contaminación*)	272	0,2573529	0,5951380	0	5
Energy efficiency (concept) *[“Eficiencia energética” (concepto)*]	272	13,5404400	8,8546180	0	68
Energy rating (*calificación energética*)	272	1,7794120	2,0908910	0	13

Enegy efficiency (total) [*Eficiencia energética (total)*]	272	15,6911800	9,7208380	0	80

Source: Mora-Sanguinetti and Atienza-Maeso (2024a).

Fig. A1. Correlation matrix of the variables included in the analysis



Source: Own elaboration.

Table A3. Definition of independent variables

Variable	Measure	Definition	Source
Innovation expenditure (InnE)	‘000€	Innovation activities are understood as any activity (financial, development or commercial) that leads to the development or adoption of innovations. It includes seven different activities: internal research and experimental development (R&D); acquisition of R&D (or external R&D); engineering, design, and other creative activities; marketing and brand creation; activities related to intellectual property rights; activities related to staff training; software development and activities related to the work of databases and activities related to the acquisition or leasing of tangible goods. The internal experimental R&D includes current expenditures and capital expenditures inside the firm **whichever the origin of the funds**. The Innovation expenditure by firms is reported at the regional level in the regions where the firms have their headquarters. According to the methodological note of the Spanish National Statistic Office,	Encuesta de Innovacion en las Empresas. National Statistical Office (Spain)
R&D personnel FTE business (RDPer)	FTE	Number of researchers, technicians and other supporting staff working in R&D activities in firms. These people	R&D personnel and researchers by sector of

		dedicate more than 90% of their working day in R&D activities.	performance, sex and NUTS 2 regions (Eurostat)
R&D expenditure business (RDE)	'000 €	Subset of the innovation expenditure. R&D expenditure in the firm includes basic R&D, applied R&D and experimental development This includes current expenditures and capital expenditures performed by the business sector	R&D personnel and researchers by sector of performance, sex and NUTS 2 regions (Eurostat)

BANCO DE ESPAÑA PUBLICATIONS

WORKING PAPERS

2440 ALEJANDRO CASADO and DAVID MARTÍNEZ-MIERA: Local lending specialization and monetary policy.

2441 JORGE ABAD, DAVID MARTÍNEZ-MIERA and JAVIER SUÁREZ: A macroeconomic model of banks' systemic risk taking.

2442 JOSEP PIJOAN-MAS and PAU ROLDAN-BLANCO: Dual labor markets and the equilibrium distribution of firms.

2443 OLYMPIA BOVER, LAURA HOSPIDO and ANA LAMO: Gender and Career Progression: Evidence from the Banco de España.

2444 JESÚS FERNÁNDEZ-VILLAVERDE, GALO NUÑO and JESSE PERLA: Taming the curse of dimensionality: quantitative economics with deep learning.

2445 CLODOMIRO FERREIRA and STEFANO PICA: Households' subjective expectations: disagreement, common drivers and reaction to monetary policy.

2446 ISABEL MICÓ-MILLÁN: Inheritance Tax Avoidance Through the Family Firm.

2447 MIKEL BEDAYO, EVA VALDEOLIVAS and CARLOS PÉREZ: The stabilizing role of local claims in local currency on the variation of foreign claims.

2501 HENRIQUE S. BASSO, MYROSLAV PIDKUYKO and OMAR RACHEDI: Opening the black box: aggregate implications of public investment heterogeneity.

2502 MARCO BARDOSCIA, ADRIAN CARRO, MARC HINTERSCHWEIGER, MAURO NAPOLETANO, LILIT POPOYAN, ANDREA ROVENTINI and ARZU ULUC: The impact of prudential regulations on the UK housing market and economy: insights from an agent-based model.

2503 IRINA BALTEANU, KATJA SCHMIDT and FRANCESCA VIANI: Sourcing all the eggs from one basket: trade dependencies and import prices.

2504 RUBÉN VEIGA DUARTE, SAMUEL HURTADO, PABLO A. AGUILAR GARCÍA, JAVIER QUINTANA GONZÁLEZ and CAROLINA MENÉNDEZ ÁLVAREZ: CATALIST: A new, bigger, better model for evaluating climate change transition risks at Banco de España.

2505 PILAR GARCÍA and DIEGO TORRES: Perceiving central bank communications through press coverage.

2506 MAR DELGADO-TÉLLEZ, JAVIER QUINTANA and DANIEL SANTABÁRBARA: Carbon pricing, border adjustment and renewable energy investment: a network approach.

2507 MARTA GARCÍA RODRÍGUEZ: The role of wage expectations in the labor market.

2508 REBECA ANGUREN, GABRIEL JIMÉNEZ and JOSÉ-LUIS PEYDRÓ: Bank capital requirements and risk-taking: evidence from Basel III.

2509 JORGE E. GALÁN: Macroprudential policy and the tail risk of credit growth.

2510 PETER KARADI, ANTON NAKOV, GALO NUÑO, ERNESTO PASTÉN and DOMINIK THALER: Strike while the Iron is Hot: Optimal Monetary Policy with a Nonlinear Phillips Curve.

2511 MATTEO MOGLIANI and FLORENS ODENDAHL: Density forecast transformations.

2512 LUCÍA LÓPEZ, FLORENS ODENDAHL, SUSANA PÁRRAGA and EDGAR SILGADO-GÓMEZ: The pass-through to inflation of gas price shocks.

2513 CARMEN BROTO and OLIVIER HUBERT: Desertification in Spain: Is there any impact on credit to firms?

2514 ANDRÉS ALONSO-ROBISCO, JOSÉ MANUEL CARBÓ, PEDRO JESÚS CUADROS-SOLAS and JARA QUINTANERO: The effects of open banking on fintech providers: evidence using microdata from Spain.

2515 RODOLFO G. CAMPOS and JACOPO TIMINI: Trade bloc enlargement when many countries join at once.

2516 CORINNA GHIRELLI, JAVIER J. PÉREZ and DANIEL SANTABÁRBARA: Inflation and growth forecast errors and the sacrifice ratio of monetary policy in the euro area.

2517 KOSUKE AOKI, ENRIC MARTORELL and KALIN NIKOLOV: Monetary policy, bank leverage and systemic risk-taking.

2518 RICARDO BARAHONA: Index fund flows and fund distribution channels.

2519 ALVARO FERNÁNDEZ-GALLARDO, SIMON LLOYD and ED MANUEL: The Transmission of Macroprudential Policy in the Tails: Evidence from a Narrative Approach.

2520 ALICIA AGUILAR: Beyond fragmentation: unraveling the drivers of yield divergence in the euro area.

2521 RUBÉN DOMÍNGUEZ-DÍAZ and DONGHAI ZHANG: The macroeconomic effects of unemployment insurance extensions: A policy rule-based identification approach.

2522 IRMA ALONSO-ALVAREZ, MARINA DIAKONOVA and JAVIER J. PÉREZ: Rethinking GPR: The sources of geopolitical risk.

2523 ALBERTO MARTÍN, SERGIO MAYORDOMO and VICTORIA VANASCO: Banks vs. Firms: Who Benefits from Credit Guarantees?

2526 STÉPHANE BONHOMME and ANGELA DENIS: Fixed Effects and Beyond. Bias Reduction, Groups, Shrinkage and Factors in Panel Data.
2527 ÁLVARO FERNÁNDEZ-GALLARDO and IVÁN PAYÁ: Public debt burden and crisis severity.
2528 GALO NUÑO: Three Theories of Natural Rate Dynamics.
2529 GALO NUÑO, PHILIPP RENNER and SIMON SCHEIDEGGER: Monetary policy with persistent supply shocks.
2530 MIGUEL ACOSTA-HENAO, MARÍA ALEJANDRA AMADO, MONTSERRAT MARTÍ and DAVID PÉREZ-REYNA: Heterogeneous UIPDs across Firms: Spillovers from U.S. Monetary Policy Shocks.
2531 LUIS HERRERA and JESÚS VÁZQUEZ: Learning from news.
2532 MORTEZA GHOMI, JOCHEN MANKART, RIGAS OIKONOMOU and ROMANOS PRIFTIS: Debt maturity and government spending multipliers.
2533 MARINA DIAKONOVA, CORINNA GHIRELLI and JAVIER J. PÉREZ: Political polarization in Europe.
2534 NICOLÁS FORTEZA and SERGIO PUENTE: Measuring non-workers' labor market attachment with machine learning.
2535 GERGELY GANICS and LLUC PUIG CODINA: Simple Tests for the Correct Specification of Conditional Predictive Densities.
2536 HENRIQUE S. BASSO and OMAR RACHEDI: Robot adoption and inflation dynamics.
2537 PABLO GARCIA, PASCAL JACQUINOT, ČRT LENARČIČ, KOSTAS MAVROMATIS, NIKI PAPADOPOULOU and EDGAR SILGADO-GÓMEZ: Green transition in the Euro area: domestic and global factors.
2538 MARÍA ALEJANDRA AMADO, CARLOS BURGA and JOSÉ E. GUTIÉRREZ: Cross-border spillovers of bank regulations: Evidence of a trade channel.
2539 ALEJANDRO CASADO and DAVID MARTÍNEZ-MIERA: Banks' specialization and private information.
2540 CHRISTIAN E. CASTRO, ÁNGEL ESTRADA GARCÍA and GONZALO FERNÁNDEZ DIONIS: Diversifying sovereign risk in the Euro area: empirical analysis of different policy proposals.
2541 RAFAEL GUNTIN and FEDERICO KOCHEN: The Origins of Top Firms.
2542 ÁLVARO FERNÁNDEZ-GALLARDO: Natural disasters, economic activity, and property insurance: evidence from weekly U.S. state-level data.
2543 JOSÉ ELÍAS GALLEGOS, ESTEBAN GARCÍA-MIRALLES, IVÁN KATARYNIUK and SUSANA PÁRRAGA RODRÍGUEZ: Fiscal Announcements and Households' Beliefs: Evidence from the Euro Area.
2544 LUIS HERRERA, MARA PIROVANO and VALERIO SCALONE: From risk to buffer: Calibrating the positive neutral CCyB rate.
2545 ESTEBAN GARCÍA-MIRALLES et al.: Fiscal drag in theory and in practice: A European perspective.
2546 TATSURO SENGA and IACOPO VAROTTO: Investment Irreversibility in a Granular World.
2547 OLYMPIA BOVER, NEZIH GUNER, YULIYA KULIKOVA, ALESSANDRO RUGGIERI and CARLOS SANZ: Family-friendly policies and fertility: What firms have to do with it?
2548 ADINA-ELENA FUDULACHE and MARIA DEL CARMEN CASTILLO LOZOYA: Demand drivers of central bank liquidity: A time-to-exit TLTRO analysis.
2549 ERIK ANDRES-ESCAYOLA, LUIS MOLINA, JAVIER J. PÉREZ and ELENA VIDAL: How economic policy uncertainty spreads across borders: the case of Latin America.
2550 MATTHIAS BURGERT, MATTHIEU DARRACQ PARIÈS, LUIGI DURAND, MARIO GONZÁLEZ, ROMANOS PRIFTIS, OKE RÖHE, MATTHIAS ROTTNER, EDGAR SILGADO-GÓMEZ, NIKOLAI STÄHLER and JANOS VARGA: Macroeconomic effects of carbon-intensive energy price changes: A model comparison.
2601 IACOPO VAROTTO: Blocking the Blockers? Diversity Matters.
2602 CARLOS CAÑIZARES MARTÍNEZ, ADRIANA LOJSCHOVÁ and ALICIA AGUILAR: Non-linear effects of monetary policy shocks on housing: Evidence from a CESEE country.
2603 DIEGO BONELLI: Inflation risk and yield spread changes.
2604 MARÍA ALEJANDRA AMADO: Macroprudential FX Regulations and Small Firms: Unintended Consequences for Credit Growth.
2605 FERNANDO ÁVALOS, BORIS HOFMANN and JOSE M. SERENA: Monetary policy and private equity acquisitions: tracing the links.
2606 RICARD GREBOL, MARGARITA MACHELETT, JAN STUHLER and ERNESTO VILLANUEVA: Assortative Mating, Inequality, and Rising Educational Mobility in Spain.
2607 PABLO AGUILAR, RUBÉN DOMÍNGUEZ-DÍAZ, JOSÉ-ELÍAS GALLEGOS and JAVIER QUINTANA: The Transmission of Foreign Shocks in a Networked Economy.
2608 ERWAN GAUTIER, CRISTINA CONFLITTI, DANIEL ENDERLE, LUDMILA FADEJEVA, ALEX GRIMAUD, EDUARDO GUTIÉRREZ, VALENTIN JOUVANCEAU, JAN-OLIVER MENZ, ALARI PAULUS, PAVLOS PETROULAS, PAU ROLDAN-BLANCO and ELISABETH WIELAND: Consumer price stickiness in the euro area during an inflation surge.
2609 MORTEZA GHOMI and SAMUEL HURTADO: RAUI: Uncertainty Indicators Built With Artificial Intelligence.
2610 MORTEZA GHOMI and EVI PAPPA: Stimulating avenues: EIB loans and returns to Public Investment.
2611 JUAN S. MORA-SANGUINETTI, CRISTINA PEÑASCO and ROK SPRUK: The impact of "Green Regulation" on firms' innovation.