



Research article

Environmental corporate social responsibility practices and firm innovation: Complementarities and empirical evidence from Spanish firms

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ABSTRACT

This study examines the complementarity effect of combining different types of environmental corporate social responsibility (ECSR) practices on firm innovation. We apply the complementarity approach to test whether the adoption of different ECSR practices (i.e. practices for fewer materials per unit produced [materials], less energy per unit produced [energy], or decreasing environmental impact [impact]) generates super-additive effects on firms' innovation, measured by innovations type: adoption, new-to-the-market, and new-to-the-firm innovation. We use data from the Spanish Community Innovation Survey for the period 2009–2014. The results show that the best combination of ECSR practices depends on the innovation type. For innovation adoption, all possible combinations of the three practices produce super-additive effects; however, the complementarity patterns differ for new-to-the-market and new-to-the-firm innovations. For new-to-the-market innovation, energy practices appear to be a key factor in fostering innovation when combined with materials or impact practices. For new-to-the-firm innovation, the combination of these three ECSR practices shows complementarity effects. These findings provide useful insights for the design of corporate social responsibility strategies.

1. Introduction

Our society currently faces important challenges related to the effects of resource scarcity, climate change, urbanisation, population growth, industrialisation, and globalisation—a situation that requires prioritising sustainability. As such, the 21st century is seen as the 'century of planetary survival' that should be based on sustainable development (SD). Since the publication of the Sustainable Development Goals (SDGs) in 2015 for the adoption of the 2030 Agenda for SD, the topic of sustainability has attracted increasing attention. Agenda 2030 aims for countries to eradicate poverty and find sustainable and inclusive solutions to ensure human rights by 2030. Moreover, firms realise that short-term profit maximisation is unsustainable [1]. In this context, both academia and firm management are exploring the role of corporate social responsibility (CSR) in business competitiveness [2], primarily because of its capacity to generate competitive advantages and better economic performance for firms [3].

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A relevant topic in the literature is the connection between CSR and innovation [4–10]. Researchers agree on the multidimensionality of the CSR concept and the need to clarify it in relation to innovation [10]. To this end, the triple bottom line (TBL) theory may provide valuable guidance. TBL theory defines CSR as a multidimensional construct with economic, social, and environmental factors as its core elements [7]. In applying the TBL model [11], the impact of economic and social dimensions on business innovativeness has received great attention in the literature, but the environmental dimension has been less explored [12,13]. Considering this literature gap and the importance of environmental sustainability, we decided to focus on environmental corporate social responsibility (ECSR) [12,14].

ECSR is a key element of CSR that has become a dominant theme in CSR reporting over the last decades [13]. ECSR involves developing a set of environmentally friendly practices to generate positive impacts on stakeholders [15] through the voluntary incorporation of environmental concerns into a firm's operational activities [16]. In other words, ECSR practices are those that reduce the negative impacts of enterprises' operations on the environment [15].

As such, ECSR practices are key strategies for achieving SDGs, especially those related to responsible consumption and production and those that build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation and experiences to mitigate the impacts of climate change [17]. Specifically, ECSR practices are relevant in achieving SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Production and Consumption) and SDG 13 (Urgent Action to Combat Climate Change and its Impacts). As previously suggested in the literature, the adoption of environment-friendly products and processes is necessary to combat climate change [18] and can promote innovation. Although a few studies have confirmed that firms that incorporate sustainable principles into their products and processes are more innovative [9,19,20], gaps on this topic remain.

Specifically, except for a few studies [9], previous literature has focused on ECSR as a single construct or on formal and certifiable processes of environmental management systems without paying attention to the role of different ECSR practices in innovation [21, 22]. Such practices have mainly been identified as energy/material reduction per unit of product or emission reduction for soil, water, and air [9,23,24]. In addition, although the importance of environmental capability complementarities has been suggested in the literature [25,26] and marginally confirmed empirically [27,28], a gap remains regarding the complementarities among different ECSR practices on innovation.

In light of the issues described above this study makes three main contributions to the literature. First, we refer to the TBL theory and focus on ECSR, one of the three CSR dimensions. CSR has mostly been treated in previous literature as a unique construct, thus limiting the understanding of the characteristics of each CSR dimension. Second, we consider the effects of different ECSR practices on innovation. Finally, we make a novel contribution to the literature by being the first to implement the complementarity approach to examine the link between ECSR practices and firm innovation. To the best of our knowledge, this approach has never been taken to analyse the ECSR–innovation link.

Using data from the Spanish Community Innovation Survey (CIS) in 2009–2014, we investigate two main research questions.

RQ1. *Do ECSR practices influence firm innovation?*

RQ2. *Does combining different ECSR practices have a complementary effect on firm innovation?*

2. Literature review

2.1. Environmental corporate social responsibility practices as drivers of innovation

The United Nations suggests that by the 2030s, it will be necessary to maintain almost twice the Earth's current capacity to maintain the global pace of production, consumption, and population growth [29]. Firms play a crucial role in transitioning to this new paradigm, for which the adoption of ECSR practices has been a focus [13].

The ECSR concept encourages the transformation of environmental concerns into management actions [30] that lead firms to modify their operating philosophy, products, activities, and equipment to reduce the impact of corporate activities on the environment [14,31]. ECSR practices are those that promote environmentally friendly products and processes through the responsible use of natural resources or enhanced practices of industrial waste management in order to reduce pollution levels, the depletion of natural resources, and the negative effects on the environment [32].

Sustainability targets, such as those related to ECSR practices, are seen as a new way to achieve innovation [33], as they help firms develop environmental innovation strategies [34,35]. Along this line, innovation is justified for reducing the material consumption levels, promoting energy efficiency, minimising CO₂ emissions, and slowing down the pernicious effects of products and processes on the environment [36,37]. Similarly, certain environmental practices can lead to the creation of new products, systems, or markets [38, 39] and enhance product differentiation [39]. Arguments that apply different theoretical approaches, such as the resource-based view (RBV) and natural resource-based view (NRBV), shed light on the ECSR practice–innovation relationship.

The RBV theory emphasises the relevance of resources that are valuable, rare, inimitable, and non-substitutable to the company [40]. From this perspective, a firm is seen as comprising a set of resources and capabilities such as those related to technology, marketing, human management, or knowledge accumulation [41] that are unique and allow firms to become more entrepreneurial, develop competitive advantages, and foster their performance [9,41–43]. As with any type of responsible practice, ECSR practices allow firms to develop intangible resources, thus reinforcing their capabilities and competitive market advantages [4].

The NRBV was developed from the RBV [44]. According to the NRBV, firms integrate the environmental dimension into their strategy and thereby generate competitive advantages that are sustainable over time [21,45–47]. Hart [44] proposed the NRBV to address the RBV's limitation of being purely internally based. According to Hart [44] a company's ability to promote eco-friendly

actions helps it develop competitive advantages by relying on three key strategic capabilities: pollution prevention, product stewardship, and sustainable development [48]. In particular, the adoption of pollution-preventive policies could help firms reduce CO2 emissions and waste, and significantly cut their production costs. By contrast, product stewardship integrates the 'voice of the environment' into the product design and development process, and thus create the potential for achieving competitive advantages. To ensure that production processes can be maintained indefinitely over time, it is critical that they be sustainable; therefore, they should consider not only the economic dimension of CSR but also the social and environmental dimensions.

Regarding the relationship between ECSR practices and innovation, the integration of environmental issues into a firm's strategy and decision-making criteria facilitates the development of practices that are more environmentally friendly and allow firms to obtain new, valuable, rare, inimitable, and non-substitutable resources, and thereby stimulate innovation [49]. Moreover, ECSR practices often create an innovative culture in a company that enhances employees' motivation and creativity, thereby increasing innovation development [12]. Thus, innovation is an essential element in designing corporate strategies to address the challenges of sustainable development successfully [44].

Porter and Van der Linde [50] point out that environmental regulations force firms to innovate, leading to operational efficiency, quality product improvements, higher customer satisfaction, and cost savings. More precisely, environmental concerns enable firms 'to eradicate inefficiencies related to product attributes (i.e. toxic materials), product design (i.e. design for reuse), or manufacturing processes (i.e. energy savings), which stimulates the development of innovations' [51] that are capable of generating competitive advantages [52], and even the sustainable development of the regional economy [53].

Drawing on the NRBV, Pekovi and Bouziri [54] identify three ways of adopting ECSR practices to promote innovation by reducing related barriers. Specifically, environmental practices help firms overcome cost, knowledge, and market barriers to innovation [54].

First, ECSR practices can facilitate cost savings by improving production processes and reducing the cost of inputs and waste disposal [44,55]. Moreover, the adoption of ECSR practices helps firms to reduce regulatory charges and other payments related to environmental issues, thereby enhancing their operative effectiveness and innovation [54,56,57]. In addition, ECSR practices can reduce labour costs as they are strongly related to labour productivity [58]. These methods of saving innovation costs further facilitate the development of innovation activities [54].

Second ECSR practices help overcome knowledge obstacles. This is because the implementation of ECSR practices usually requires employees to engage in training programs that improve their knowledge and experience [59], and firms to recruit and attract more talented employees [9,60]. In addition, communication is typically enhanced, as the implementation of friendly environmental practices improves personal contact and facilitates knowledge transfer [54,58]. Relatedly, as Pekovic and Bouziri [54] note, adopting ECSR practices boosts employees' involvement and engagement in the firm's routine activities, improves their commitment to the firm's goals, and promotes the establishment of personal interrelations and creativity, among others [61–65]. As a result of these improvements in human capital, a positive effect on innovation can be expected [54,66].

Finally, ECSR practices can help overcome the market barriers to innovation, as environmentally responsive firms tend to manage their operations according to customer demands [67]. Thus, consumer confidence in the company increases, leading to more stable and lasting relationships over time [54]. This also improves access to valuable information and reduces the market barriers to innovation [68]. Second, ECSR practices encourage firms' cooperation with their suppliers [69], which could help them overcome market barriers to innovation [54].

Regarding empirical evidence, previous research has confirmed a positive effect of ECSR on innovation. Branco and Rodrigues [70] deem pollution prevention practices to be an important source of business innovation through, for example, the development of new environmentally friendly processes and products. Similarly, McWilliams and Siegel [19] find that ECSR practices lead to higher firm innovation because they promote R&D investments. García-Piqueres and García-Ramos [9] conclude that ECSR practices have a positive effect on different innovation types (product, process, and organisational innovation). Forcadell et al. [12] confirm the positive effect of ECSR on small and medium-sized enterprises (SMEs), product and process innovation, and R&D efforts. More recently, Torrecillas and Fernández [18] confirm the positive effect of ECSR on product, process, new-to-the-market, and new-to-the-firm innovations in Spanish firms. Building on these arguments, we propose.

H1. *ECSR practices have a positive effect on innovation.*

2.2. Complementarities among different environmental corporate social responsibility practices on innovation

Complementarity means that the joint adoption of different activities entails super-additive performance effects compared with the performance of individually adopted actions [71,72]. The previous literature suggests that this is also true for socially responsible practices [73]. In particular, previous research [27] has combined the RBV with asset complementarity theory (ACT) [74] to approach complementarities in the case of environmental practices.

Specifically, the RBV perspective suggests that companies can obtain significant competitive advantages through the simultaneous adoption of different actions and resources that are related to each other and whose joint adoption allows them to reinforce each other [40]. Thus, a combination of these actions and resources results in greater innovation [2,10]. Hence, adopting different responsible practices can lead firms to gain competitive advantages that differentiate them from other organisations [75].

Synergies arising from the simultaneous adoption of different CSR practices can be a source of competitive advantage for companies [73] as they facilitate the acquisition of resources that are key to ensuring their long-term success and therefore, their survival through sustainable growth [76,77]. Moreover, by improving and strengthening the relationships established between the company and different stakeholders, conflicts can be reduced or the process of resolving them may be improved [73].

According to ACT, complementary assets are the resources required to capture the benefits associated with a strategy, technology, or innovation [27,78]. Research suggests that the adoption of several ECSR practices allows firms to develop unique and inimitable capabilities and routines that foster their competitive advantage and turnover, thus allowing them to become more efficient (i.e. use fewer resources or decrease pollution abatement) [27]. For instance, practices developed to reduce carbon emissions allow firms to enhance the tacit capabilities and technical skills of teams, which can be redeployed to reduce energy use per unit [26,27].

Similarly, we find arguments based on Porter's theory that support the complementarity hypothesis for the case of environmental strategies/practices. Porter Hypothesis (PH), which relies on a systemic approach [23], defends the idea that 'strategy is manifested in the way in which activities are configured and linked together' [79]. In addition, PH suggests that although additional innovations induced by regulations, such as environmental ones, present opportunity costs, their gross benefits may be higher [23]. Similarly, some seminal papers applying PH [50,80,81] consider that environmental regulations represent an important source of business innovation that can lead to competitive advantages to the extent that they promote the use of new resources and processes that are environmentally friendly, pollute less, and are more efficient [53]. PH suggests that there is no trade-off between financial results and environmental improvement, which has traditionally been pointed out in the financial literature. In particular, some studies that have addressed the issue of PH [82] point out that it is necessary to restructure corporate strategy such that training programs that promote skills development are emphasised to allow the company to adopt integrated and more complex environmental actions, such as recycling practices and the reduction of polluting emissions. Accordingly, we propose.

H2. Different ECSR practices may complement each other.

3. Methodology

3.1. Data

The data used in the empirical analysis are from six consecutive waves of the Spanish Community Innovation Survey (CIS) from 2009 to 2014.¹

The CIS is a survey of the European Commission and Eurostat, carried out by many European Union member states, and has been used by numerous research papers in both the innovation economics and management fields [83–86]. The design of the CIS is based on the guidelines of the Oslo Manual, which intends to support national statistical offices and other institutions in the development of a global statistical information infrastructure with high value for both researchers and policymakers. European countries pre-test the survey for reliability, validity, and interpretability of the data [10,87].

The Spanish CIS, collected by the Spanish National Statistics Institute (INE) is available in the Technological Innovation Panel (PITEC), and similar to other CIS questionnaires. It provides information about general firm characteristics and firms' innovation activities.

Our final sample is an unbalanced panel of firms with 57,008² observations in the manufacturing and services sectors.

3.2. Methods and variables

3.2.1. Complementarity approach

To analyse the existence of complementarities, we rely on supermodularity theory (ST) [88,89]. This theory holds that when complementarity exists, gains in the added value derived from the combination of two or more resources, factors, or actions are higher than the sum of the individual added value derived from each resource, factor, or action individually [27,73]. Therefore, complementarity is not just the association between practices, but also the positive synergy implied to exist among the combined resources, factors, or actions [90]. Consistent with this argument and within the context of our study, complementarity can be explained as follows.

- If the level of firm innovation obtained using one ECSR practice is greater when complementary practices are simultaneously implemented than when they are not, complementarity exists, and
- If the level of firm innovation obtained using one ECSR practice is greater when certain practices are not implemented simultaneously, complementarity does not exist.

Supermodularity is the mathematical equivalent of the idea that the gain achieved by increasing all the components is greater than the sum of the gains obtained from each individual increases [88]. Therefore, supermodularity exists when all possible pairings of ECSR practices exhibit complementarity [90] such that the implementation of one ECSR practice leads to a higher positive impact on firm innovation when the complementary practice is undertaken simultaneously than when it is not.

As ST suggests, in the creation of a supermodular function, the best way to analyse complementarity empirically, as with previous

¹ Although at this moment the most recent available data in the PITEC correspond to 2016, the period that best suited our research objectives is 2009–2014 as this allows homogeneous longitudinal data on the measurement of the variables analysed.

² This breaks down to 10,796 (18.94%) firms in 2009; 10,380 (18.21%) firms in 2010; 9977 (17.50%) firms in 2011; 9612 (16.86%) firms in 2012; 9172 (16.09%) firms in 2013, and 7071 (12.40%) firms in 2014.

research [10,71], is to test if the objective function is supermodular [91] by looking for conditional complementarity. To this end, we conduct a pairwise complementarity test between two ECSR practices under the following conditions.

- First, the third practice must not be simultaneously undertaken.
- Second, the third practice must be simultaneously undertaken.

Specifically, we establish a function F for the three alternative activities X_1 , X_2 , and X_3 , where X_1 (Materials) is the use of fewer materials per unit produced, X_2 (Energy) represents the use of less energy per unit produced, and X_3 (Impact) means reducing the environmental impact. Each company can perform each of these activities; thus, a total of 2^3 plausible combinations of these practices exist.

$\{X_1, X_2, X_3\} = \{000\}, \{001\}, \{010\}, \{100\}, \{011\}, \{110\}, \{101\}, \{111\}$, where $\{000\}$ represents the non-adoption of any practice and $\{111\}$ represents the combined adoption of all three practices.

We consider innovation as the objective function (F):

$$F(X_1, X_2, X_3, Z) = \beta_{000}(1-X_1)(1-X_2)(1-X_3) + \beta_{100}X_1(1-X_2)(1-X_3) + \beta_{010}(1-X_1)X_2(X_3) + \beta_{001}(1-X_1)(1-X_2)X_3 + \beta_{110}X_1X_2(1-X_3) + \beta_{101}X_1(1-X_2)X_3 + \beta_{011}(1-X_1)X_2X_3 + \beta_{111}X_1X_2X_3 + \beta_Z Z + e \quad (1)$$

We define the conditions for complementarity as described below.

Complementarity between Materials and Energy:

$$\begin{cases} f(110) + f(000) \geq f(100) + f(010) & (\text{Impact is not present}) \\ f(111) + f(001) \geq f(011) + f(101) & (\text{Impact is present}); \end{cases}$$

Complementarity between Materials and Impact:

$$\begin{cases} f(101) + f(000) \geq f(100) + f(001) & (\text{Energy is not present}) \\ f(111) + f(010) \geq f(110) + f(011) & (\text{Energy is present}); \text{ and} \end{cases}$$

Complementarity between Energy and Impact:

$$\begin{cases} f(011) + f(000) \geq f(010) + f(001) & (\text{Materials is not present}) \\ f(111) + f(100) \geq f(110) + 101 & (\text{Materials is present}). \end{cases}$$

3.2.2. Dependent variables

Firm innovation is the dependent variable. In particular, we use three measures as proxies of innovation: adoption of innovation, new-to-the-market innovation, and new-to-the-firm innovation, following previous studies [87,92–96]. First, we approach innovation with a general view that defines innovation in terms of whether a product, process, organisational, and/or commercial innovation has been adopted [92,97,98]. This approach is rooted in Schumpeter's revolutionary work [99]. From this perspective 'innovation might involve goods, process technologies, customer–supplier interactions, organisational practices, and management' [100]. Moreover, the Oslo Manual [101] classifies innovation into four types: product, process, organisational, and marketing innovation.³ To obtain this information from firms, the CIS surveys asked whether companies had introduced one of these innovation types to four different cases. Based on both approaches and to measure the firm's adoption of innovations, we construct our first dependent variable ($\text{Adoption Innovation}_{it}$) as follows.

- Adoption innovation ($\text{Adoption Innovation}_{it}$) is a dummy variable that takes the value of 1 if firm i introduced product, process, organisational, and/or commercial innovation over the two previous years and 0 otherwise.

Second, we approach innovation in two ways based on its degree of novelty [87]. According to the Oslo Manual [101], innovations can be new to the market or firm. Regarding the former, innovations 'new to the market' are related to the introduction of new products or services for the first time in the market⁴ and generally occur in the early stages of development of a new technology [94, 96]. Innovations 'new to the firm' are related to products or services existing in the company and thus, are usually developed at the technological frontier throughout the life of the product or service [96]. The Oslo Manual states that although all product, process, organisational, and marketing innovations may have been previously adopted by other firms, they may be new to the firm [101]. CIS survey questionnaires ask about this issue, specifically the percentage of turnover generated by new-to-the-market or new-to-the-firm

³ The Third Edition of the Oslo Manual [101] identifies four categories of innovation types (product, process, organisational, and marketing innovation). Each innovation type is defined as follows [101, p. 16–17]. - Product Innovation: significant changes in the capabilities of goods or services (entirely new goods and services and significant improvements to existing products). - Process Innovation: significant changes in production and delivery methods. - Organizational Innovation: the implementation of new organizational methods as (changes in: business practices, workplace organization, or the firm's external relations). - Marketing Innovation: the implementation of new marketing methods (changes in: product design and packaging, product promotion and placement, or methods for pricing goods and services).

⁴ The Oslo Manual [101] defines 'market' as 'the firm and its competitors and it can include a geographic region or product line' [101].

innovations. From this information, we generate two additional dependent variables (Market Innovation_{it} and Firm Innovation_{it}), constructed as follows.

- New-to-the-market innovation (Market Innovation_{it}) is defined as the firm's turnover over the total number of products or services that are new to the market.
- New-to-the-firm innovation (Firm Innovation_{it}) is defined as the firm's turnover over the total number of products or services that are new to the firm but not to the market.

To estimate the model for Adoption Innovation_{it}, we use a probit random effects approach because in contrast to the fixed effect model, it solves the 'incidental parameter' problem [102,103]. In addition, we use panel data, as it is useful in controlling for heterogeneity and dealing with the effects of using time-series or cross-sectional data [102–105]. The specifications are as follows:

$$\text{Probit}(p(\text{Adoption Innovation}_{it}^*)) = \beta_0 + \beta_1 E_{it} + \beta_2 Z_{it} + \epsilon_{it} + \alpha_i, \quad (2)$$

where ECSR practices are represented by E_{it} , and control variables are captured in Z_{it} .

To estimate the models for Market Innovation_{it} and Firm Innovation_{it}, similar to Ovuakpoire et al. [87] and Haus-Reve et al. [94], we use a Tobit model because Market Innovation_{it} and Firm Innovation_{it} are double-censored variables ranging from 0 to 1. We conduct a robustness test to check for inconsistent results under the assumption that residuals follow a normal distribution. To this end, and after taking the log-transformation with a constant added to original values of Market Innovation_{it} and Firm Innovation_{it}, we use a Tobit model [10]. The specifications for both estimations are as follows:

$$\text{Market Innovation}_{it}^* = \beta_0 + \beta_1 E_{it} + \beta_2 Z_{it} + \epsilon_{it} + \alpha_i \quad (3)$$

$$\text{Firm Innovation}_{it}^* = \beta_0 + \beta_1 E_{it} + \beta_2 Z_{it} + \epsilon_{it} + \alpha_i, \quad (4)$$

where ECSR practices are represented by E_{it} , and control variables are captured in Z_{it} .

3.2.3. Independent variables

The independent variables used in this study measure the environmentally responsible practices and their combination.

ECSR practices have become key tools for firms to increase their commitment to resource sustainability and global warming. The European Commission links them to resource efficiency, which focuses on using natural resources sustainably without exceeding the Earth's boundaries, and on reducing the environmental impact of the exploitation of natural resources [106].

One of the survey questions asked whether the innovation carried out by the company sought to reduce the use of materials per unit produced, energy per unit produced, or the environmental impact. Consistent with previous literature, each of these three variables takes a value of 1 if the firm has given these objectives high or medium importance, and a value of 0 if low or null [18,23,24]. For the analyses, a total of eight exclusive ECSR practices are included in the model: Materials_{it} (1,0,0), Energy_{it} (0,1,0), Impact_{it} (0,0,1), Materials&Energy_{it} (1,1,0), Materials&Impact_{it} (1,0,1), Energy&Impact_{it} (0,1,1), Materials&Energy&Impact_{it} (1,1,1), and NoMaterials&NoEnergy&NoImpact_{it} (0,0,0).

3.2.4. Control variables

The following control variables are also included in the empirical study to address firm heterogeneity [10,92]: Internal R&D expenditures (Internalrd_{it}), external R&D expenditures (Externalrd_{it}), and cooperation (Cooperation_{it}), as well as group (Group_{it}), size (Size_{it}), industry, and dummies of time period.

Table 1
Descriptive statistics.

Variable	Mean	S.D.
Adoption Innovation _{it}	0.678	0.467
Firm Innovation _{it}	0.074	0.201
Market Innovation _{it}	0.101	0.242
Materials _{it}	0.012	0.110
Energy _{it}	0.007	0.086
Impact _{it}	0.052	0.223
Materials&Energy _{it}	0.050	0.219
Materials&Impact _{it}	0.012	0.112
Energy&Impact _{it}	0.020	0.141
Materials&Energy&Impact _{it}	0.346	0.475
NoMaterials&NoEnergy&NoImpact _{it}	0.175	0.380
Internalrd _{it}	0.429	0.495
Externalrd _{it}	0.204	0.403
Cooperation _{it}	0.123	0.328
Group _{it}	0.424	0.494
Size _{it}	325.2996	1568.593

Note: Mean and Standard Deviation of variables are shown in Table 1.

Table 2

Pair-wise correlations between independent variables.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Internalrd _{it}												
2. Externalrd _{it}	0.4500***											
3. Cooperation _{it}	0.2838***	0.2532***										
4. Group _{it}	0.0831***	0.1278***	0.1213***									
5. Size _{it} ^a	0.0813***	0.1264***	0.1035***	0.4460***								
6. Materials _{it}	0.0260***	0.0007	-0.0042	-0.0091**	-0.0073*							
7. Energy _{it}	0.0026	0.0112*	0.0048	-0.0067	0.0006	-0.0098*						
8. Impact _{it}	0.1157***	0.0732***	0.0697***	0.0082*	0.0022	-0.0264***	-0.0206***					
9. Materials&Energy _{it}	0.0589***	0.0190***	0.0045	-0.0127**	-0.0231***	-0.0259***	-0.0202***	-0.0547***				
10. Materials&Impact _{it}	0.0657***	0.0439***	0.0307***	-0.0054	0.0118**	-0.0127**	-0.0099*	-0.0268***	-0.0263***			
11. Energy&Impact _{it}	0.0769***	0.0519***	0.0530***	0.0223***	0.0269***	-0.0161***	-0.0126**	-0.0340***	-0.0333***	-0.0164***		
12. Materials&Energy&Impact _{it}	0.4929***	0.3122***	0.2138***	0.1112***	0.1191***	-0.0813***	-0.0636***	-0.1720***	-0.1685***	-0.0827***	-0.1048***	
13. NoMaterials&NoEnergy&NoImpact _{it}	-0.0404***	-0.0500***	-0.0229***	-0.0236***	-0.0448***	-0.0515***	-0.0403***	-0.1089***	-0.1067***	-0.0524***	-0.0664***	-0.3355***

Note: * denotes $p < 0.05$; **, $p < 0.01$; and ***, $p < 0.001$. ^a denotes logarithmised variables

4. Results and analysis

Table 1 presents the descriptive statistics of all variables. The pairwise correlations between the independent variables are shown in Table 2. As the correlation coefficients are lower than 0.65 [107], the variance inflation factors range from 1.01 to 2.91, and the condition indices are all lower than 30 [108], we deem that multicollinearity is not an issue here.

Table 3 summarises the results of the regression analysis.

The effects of the control variables on the dependent variable are contingent on the specific innovation measures considered in each case. Specifically, Internal R&D has a positive effect on Market Innovation ($\beta = 0.0406$ and $p = 0.000$; $\beta = 0.0322$ and $p = 0.001$) and on Firm Innovation ($\beta = 0.0259$ and $p = 0.000$; $\beta = 0.0217$ and $p = 0.002$), whereas its effect on Adoption of Innovation is negative ($\beta = -0.0931$ and $p = 0.011$).

Meanwhile, External R&D and Cooperation have a positive and significant effect on Market Innovation ($\beta = 0.0125$ and $p = 0.000$; $\beta = 0.0070$ and $p = 0.000$), but their effect on Firm Innovation and Adoption of Innovation is not significant. Group has a positive effect on Adoption of Innovation ($\beta = 0.1330$ and $p = 0.000$), whereas Firm Size has a positive effect on Adoption of Innovation ($\beta = 0.1662$ and $p = 0.000$), and a negative effect on Market Innovation ($\beta = -0.0024$ and $p = 0.003$; $\beta = -0.0016$ and $p = 0.000$).

Regarding the independent variables, a consistent result is found. Specifically, for the three innovation measures (Adoption of Innovation, Market Innovation, and Firm Innovation), the eight possible combinations of the three ECSR practices considered (material, energy, and impact) have a positive effect on innovation, as shown by their positive and significant coefficients. This empirical evidence strongly supports Hypothesis 1, which states that ECSR practices positively affect innovation. The results show that ECSR practices that focus on reducing the use of materials, energy, and environmental impact lead to more innovation, both individually and jointly.

Table 4 summarises the results of the complementarity tests. These tests are based on previous regressions (Table 3). The conditions of supermodularity fit when Chi2 significance meets the condition. As shown on Table 4, the complementarity between ECSR practices

Table 3

Results of the Probit and Tobit estimations—Dependent variables: Adoption Innovation_{it}, Market Innovation_{it}, Log transformation of Market Innovation_{it}, Firm Innovation_{it}, Log transformation of Firm Innovation_{it}.

	Adoption Innovation _{it}	Market Innovation _{it}	Log transformation of Market Innovation _{it}	Firm Innovation _{it}	Log transformation of Firm Innovation _{it}
Materials _{it}	3.7895 (0.1257)***	0.0485 (0.0071)***	0.0375 (0.0052)***	0.1443 (0.0088)***	0.1065 (0.0063)***
Energy _{it}	3.8956 (0.1632)***	0.0794 (0.0089)***	0.0594 (0.0065)***	0.0887 (0.0109)***	0.0681 (0.0078)***
Impact _{it}	3.4324 (0.0656)***	0.0663 (0.0041)***	0.0509 (0.0030)***	0.1084 (0.0050)***	0.0811 (0.0036)***
Materials&Energy _{it}	3.6094 (0.0684)***	0.0568 (0.0040)***	0.0437 (0.0029)***	0.1186 (0.0049)***	0.0888 (0.0035)***
Materials&Impact _{it}	3.6948 (0.1227)***	0.0725 (0.0073)***	0.0569 (0.0053)***	0.1342 (0.0089)***	0.1008 (0.0064)***
Energy&Impact _{it}	3.6218 (0.0968)***	0.0732 (0.0059)***	0.0562 (0.0043)***	0.1025 (0.0072)***	0.0782 (0.0052)***
Materials&Energy&Impact _{it}	3.7111 (0.0498)***	0.0719 (0.0028)***	0.0564 (0.0020)***	0.1290 (0.0034)***	0.0985 (0.0024)***
NoMaterials&NoEnergy&NoImpact _{it}	3.1381 (0.0433)***	0.0506 (0.0025)***	0.0387 (0.0018)***	0.1147 (0.0031)***	0.0850 (0.0022)***
Internalrd _{it}	-0.0931 (0.0365)**	0.0406 (0.0024)***	0.0322 (0.0017)***	0.0259 (0.0029)***	0.0217 (0.0021)***
Externalrd _{it}	0.0564 (0.0377)	0.0125 (0.0024)***	0.0100 (0.0017)***	-0.0042 (0.0029)	-0.0017 (0.0021)
Cooperation _{it}	0.0499 (0.0412)	0.0070 (0.0026)***	0.0056 (0.0019)**	0.0032 (0.0032)	0.0027 (0.0023)
Group _{it}	0.1330 (0.0344)***	-0.0021 (0.0025)	-0.0014 (0.0018)	7.27e-06 (0.0030)	0.0001 (0.0021)
Size _{it}	0.1662 (0.0108)***	-0.0024 (0.0008)**	-0.0016 (0.0005)**	0.0001 (0.0009)	0.0003 (0.0006)
Sector dummies	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes
Constant	-2.2753 (0.1444)***	0.0178 (0.0111)	0.0126 (0.0082)	-0.0142 (0.0132)	-0.0110 (0.0094)
σ	1.2245 (0.0215)				
ρ	0.5999 (0.0084)				
Sigma		0.1134 (0.0010)***	0.0844 (0.0007)***	0.1287 (0.0012)	0.0930 (0.0009)
Log Likelihood	-15764.147	18764.216	36812.993	7093.2077	26290.541
Wald chi ²	8665.95***	3563.09***	4075.58***	4031.84***	4695.41***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 4
 Complementarity tests between environmental corporate social responsibility practices.

	Adoption Innovation _{it}		Market Innovation _{it}		Log transformation of Market Innovation _{it}		Firm Innovation _{it}		Log transformation of Firm Innovation _{it}	
	Chi2	P-value	Chi2	P-value	Chi2	P-value	Chi2	P-value	Chi2	P-value
Materials–Energy Complementarity										
First condition (Impact = 0): $f(110) + f(000) \geq f(100) + f(010)$	20.72	0.0000	3.08	0.0795	2.88	0.0900	0.00	0.9763	0.01	0.9370
Second condition (Impact = 1): $f(111) + f(001) \geq f(101) + f(001)$	1.29	0.2569	0.34	0.4252	0.69	0.4051	0.00	0.9507	0.01	0.9364
Materials–Impact Complementarity										
First condition (Energy = 0): $f(101) + f(000) \geq f(100) + f(001)$	5.05	0.0247	0.64	0.4236	0.91	0.3414	0.09	0.7703	0.04	0.8330
Second condition (Energy = 1): $f(111) + f(010) \geq f(110) + f(011)$	1.83	0.1760	0.20	0.6559	0.09	0.7644	1.55	0.2137	1.28	0.2575
Energy–Impact Complementarity										
First condition (Materials = 0): $f(011) + f(000) \geq f(010) + f(001)$	9.25	0.0024	4.090	0.0432	3.80	0.0513	2.29	0.1305	2.15	0.1424
Second condition (Materials = 1): $f(111) + f(100) \geq f(110) + f(101)$	0.96	0.3279	5.07	0.0243	5.44	0.0197	6.97	0.0083	6.96	0.0083

Note: * denotes $p < 0.1$.

6

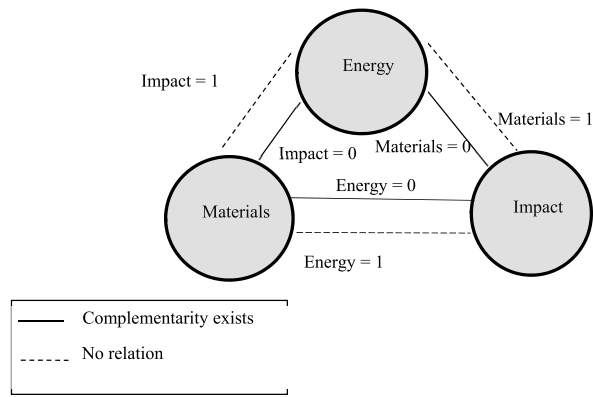


Fig. 1. Complementarities among environmental corporate social responsibility practices for Adoption Innovation. Source: Authors’ own elaboration based on Ballot et al. (2015)

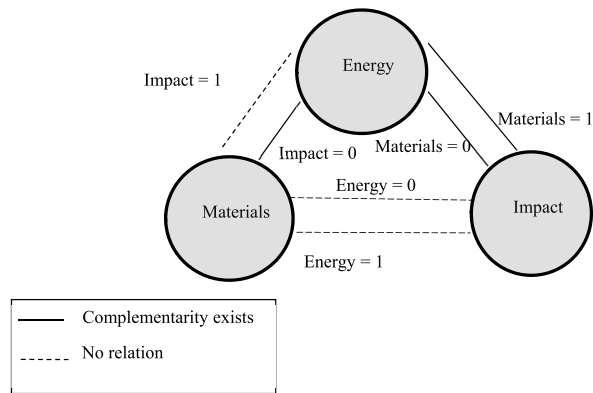


Fig. 2. Complementarities among environmental corporate social responsibility practices for Market Innovation.

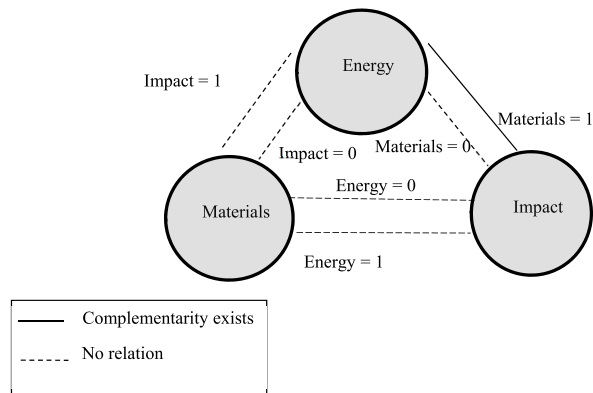


Fig. 3. Complementarities among environmental corporate social responsibility practices for Firm Innovation.

varies according to the type of ECSR practices combined, as well as to the innovation measure considered.

For the adoption of product, process, organisational, or commercial innovations, the test confirms pairwise complementarity between materials and energy when impact is not present, between materials and impact when energy is not present, and between energy and impact when materials are not present. These results suggest that the combination of such ECSR practices has a super-additive effect on the adoption of innovations. As previously presented, relying on ST suggests that the adoption of innovation (product, process, organisation, or commercial innovation) is greater when these practices are present simultaneously than when they are not [90]. In other words, when firms implement ECSR practices aimed at reducing energy consumption per unit produced, the adoption of innovation is enhanced when the firm also implements ECSR practices to reduce the environmental impact of its activities

Table 5
Summary of hypotheses and results.



Hypothesis	Results
H1: ECSR practices have a positive effect on innovation.	Accepted for the three measures of innovation
H2: Different ECSR practices may complement each other.	Partially accepted: complementarity between ECSR practices depends on the combination of practices and the innovation measure (see Table 6)

Note: ECSR means environmental corporate social responsibility.

Table 6
Summary of Complementarities among ECSR practices on Adoption Innovationit, Market Innovationit, and Firm Innovationit.

Innovation Measure	Materials ECSR	Energy ECSR	Impact ECSR	Complementarity
Adoption Innovationit			Not present	H2 accepted
		Not present		H2 accepted
	Not present			H2 accepted
			Present	H2 rejected
		Present		H2 rejected
Market Innovationit			Not present	H2 accepted
	Present			H2 accepted
	Not present			H2 accepted
			Present	H2 rejected
		Not present		H2 rejected
Firm Innovationit	Present			H2 accepted
	Not present			H2 rejected
			Not present	H2 rejected
			Present	H2 rejected
		Not present		H2 rejected
	Present		H2 rejected	

Notes:

-  Complementarity exists (H2 is accepted)
-  Complementarity doesn't exist (H2 is rejected)

or to reduce the consumption of materials per unit. The same occurs when firms implement ECSR practices to reduce the consumption of materials and energy per unit produced.

Regarding market innovations, the results show that complementarity exists between materials and energy practices when impact practices are not present, and between energy and impact practices with and without the presence of materials practices. This means that when firms implement practices to reduce energy consumption, the effect is greater on the proportion of their turnover to the total number of products and services that are new to the market when they simultaneously reduce the consumption of materials or reduce the environmental impact [90].

Finally, complementarities for firm innovation exist only in the case of a combination of energy and impact practices when materials practices are also present. Thus, if firms implement ECSR practices to reduce energy consumption and environmental impact, the proportion of their innovation turnover to the total number of products and processes that are new to these firms is greater when they also implement ECSR practices aimed at reducing the consumption of materials than if otherwise [90]. In other words, such practices are complementary.

These results partially confirm Hypothesis 2, which states that the complementarity between ECSR practices depends on the combination of practices and the innovation measure.

Fig. 1, 2, and 3 graphically show the complementarities among the ECSR practices for each of the three innovation measures used, whereas Table 5 and 6 summarise the hypotheses and main results obtained regarding complementarities.

5. Discussion

This study investigated the link between ECSR and innovation. Specifically, we tested the direct and complementary effects of different ECSR practices (materials, energy, and impact practices) on innovation. Although previous research has confirmed the positive effect of ECSR on innovation, little is understood about the effects of different ECSR practices on innovation and the complementarity between them.

Consistent with previous literature, this longitudinal study based on Spanish firms confirms that ECSR practices stimulate innovation [9,12,18–20]. The eight possible combinations of the three ECSR practices analysed here (materials, energy, and impact) show a positive effect on the three innovation measures considered (adoption of innovation, new-to-the-market innovation, and new-to-the-firm innovation). In other words, our results are robust to the three proxies used for innovation and are consistent with the NRBV's arguments regarding the valuable role of ECSR practices in improving firms' innovativeness. In this sense, the integration of environmental issues into a firm's strategy seems to stimulate the development of more initiatives that are environmentally friendly, thus allowing firms to obtain new resources that have a positive effect on firm innovation [49] because of their valuable nature [54]. From this perspective, environmental regulations appear to force firms to innovate, resulting in better operational efficiency, improved product quality, increased added value for customers, and cost savings [50]. Finally, the results reveal that the implementation of ECSR practices helps firms reduce obstacles to innovation (i.e. cost, knowledge, and market barriers) [54]. Hence, our results, developed based on the research carried out by Porter and Van der Linde [50] and He et al. [43], advance the previous literature as it shows the possibility of obtaining competitive advantages by implementing environmental actions through the development of innovations [12]. In addition, our results extend this research field, as we find that this positive effect is not contingent on the type of ECSR practice applied; therefore, our results are more robust than those in previous research.

Regarding the complementarity between different ECSR practices, both the RBV and ACT [74] suggest that the adoption of several ECSR practices allows firms to develop unique and inimitable capabilities and routines that foster competitive advantage and turnover and allow them to become more efficient [27]. To adopt ECSR practices effectively, PH [82] attaches great importance to staff training and their acquisition of competencies. As such, it is necessary to review the company's strategy and redefine it to include the adoption of integrated green strategies such as recycling initiatives and the reduction of polluting emissions.

The results also extend previous literature that applies the complementarity approach to examine the ECSR–innovation link. To the best of our knowledge, this approach has never been applied to this context. In essence, our results highlight the validity of the RBV, ACT, and PH arguments in explaining the complementarity between different ECSR practices and their relationships with innovation.

Specifically, the results suggest that combining different ECSR practices has a super-additive effect on innovation. This finding is consistent with the argument that an adequate implementation of the environmental dimension of CSR requires 'adopting integrated and more complex green strategies and not only "end-of-pipe" technologies' [109]. The results also confirm that the best combination of ECSR practices depends on the innovation type.

Regarding the innovation measures, our results on complementarity are robust as all three possible combinations of ECSR practices show super-additive effects on innovation. However, for new-to-the-market innovations, energy practices emerge as a fundamental axis in fostering innovation when combined with materials or impact practices. By contrast, the combination of the three ECSR practices reveals complementarity effects for new-to-the-firm innovations.

6. Conclusions

The results allow us to answer the research questions formulated at the beginning of the study, namely, 'RQ1: Do ECSR practices influence firm innovation?' and 'RQ2: Does combining different ECSR practices have a complementary effect on firm innovation?'. Regarding RQ1 we conclude that ECSR practices influence firm innovation. More precisely, the three ECSR practices (materials, energy, and impact practices) positively affect the three innovation measures considered (adoption of innovation, new-to-the-market innovation, and new-to-the-firm innovation). However, the results for RQ2 suggest that the complementarity of ECSR practices is contingent on both the type of ECSR practice and innovation measure considered.

Hence, this study provides important insights for firms to overcome the challenges arising from the need to preserve the environment through the efficient use of natural resources.

Furthermore, this study has implications for practitioners. In particular, it shows that ECSR practices related to the efficient use of energy are highly complementary, especially in the case of new-to-the-market innovations, which have been pointed out in the literature as the most relevant type of innovation for achieving overall environmental sustainability [110]. This finding places the efficient use of energy as a key business practice, not only for realising innovations, but also for promoting the development of innovations that generate the best opportunities to contribute to sustainability at the social level. This result is likewise supported from a practical perspective by the measures taken by different international institutions, as the inefficient use of exhaustible energy sources is one of the biggest barriers to achieving a sustainable future. Energy saving in production processes is a key element of the global energy problem, and is on the agenda of international regulators.

Furthermore, the results may help managers in their decision-making, as they offer selection criteria on which ECSR practices to implement. Specifically, the results suggest that different ECSR actions are required depending on the type of innovation (i.e. adoption of innovation, new-to-the-firm, and/or new-to-the-market innovation) [93]. Furthermore, to foster innovation, firms can benefit from a combination of efficient energy use with any of the other two types of ECSR practices. Therefore, it is not optimal to manage all ECSR practices in a homogeneous and aggregated manner as a single element; rather, it may be necessary to pay attention to each ECSR practice individually and look for the best way to combine them to obtain competitive advantages through innovation. Currently,

promoting responsible innovation through ECSR practices is crucial for Earth's sustainability.

This study has some limitations. First, it focuses on a single country, Spain, which has special characteristics in the context of Europe, such as lower comparative levels of innovation activities and a higher number of SMEs in its productive structure [111]. These two factors prevent the generalisation of our results to other contexts. Second, the construction of the ECSR and innovation variables was conditioned by the type of information available in the CIS. In addition, the declarative nature of the questions in the survey could lead to biased results. Other relevant information was also excluded from the survey such as the length of time ECSR practices have been in place and their maturity level, which could point to new research opportunities. Moreover, even though ECSR practices of energy and material reduction may be efficient and improve the overall sustainability of a company, they may not address other relevant aspects such as overconsumption. Further research is needed to analyse the efficiency of ECSR practices jointly with those related to overconsumption.

CRedit authorship contribution statement

Gema García-Piqueres: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. **Rebeca García-Ramos:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- [1] H. Sarwar, J. Aftab, M. Ishaq, M. Atif, Achieving business competitiveness through corporate social responsibility and dynamic capabilities: an empirical evidence from emerging economy, *J. Clean. Prod.* 386 (2023) 135820, <https://doi.org/10.1016/j.jclepro.2022.135820>.
- [2] R.R. Ahmed, D. Streimikiene, Environmental issues and strategic corporate social responsibility for organizational competitiveness, *J. Compet.* 13 (2) (2021) 5–22, <https://doi.org/10.7441/joc.2021.02.01>.
- [3] C. Le Bas, N. Poussing, Do non-technological innovations and CSR matter for environmental innovation? An empirical analysis of a sample of innovators, *Int. J. Sustain. Dev.* 20 (2017) 68–91, <https://doi.org/10.1504/IJSD.2017.083483>.
- [4] I. Gallego-Alvarez, J.M. Prado-Lorenzo, I.-M. García-Sánchez, Corporate social responsibility and innovation: a resource-based theory, *Manag. Decis.* 49 (2011) 1709–1727, <https://doi.org/10.1108/00251741111183843>.
- [5] R. Bocquet, C. Le Bas, C. Mothe, N. Poussing, Are firms with different CSR profiles equally innovative?. Empirical analysis with survey data, *Eur. Manag. J.* 31 (2013) 642–654, <https://doi.org/10.1016/j.emj.2012.07.001>.
- [6] I. Martínez-Conesa, P. Soto-Acosta, M. Palacios-Manzano, Corporate social responsibility and its effect on innovation and firm's performance: an empirical research in SMEs, *J. Clean. Prod.* 142 (2017) 2374–2383, <https://doi.org/10.1016/j.jclepro.2016.11.038>.
- [7] J. Guerrero-Villegas, L. Sierra-García, B. Palacios-Florencio, The role of sustainable development and innovation on firm Performance, *Corp. Soc. Responsib. Environ. Manag.* 25 (2018) 1350–1362, <https://doi.org/10.1002/csr.1644>.
- [8] E. Bacinello, G. Tontini, A. Alberton, Influence of maturity on corporate social responsibility and sustainable innovation in business performance, *Corp. Soc. Responsib. Environ. Manag.* 27 (2) (2020) 749–759, <https://doi.org/10.1002/csr.1841>.
- [9] G. García-Piqueres, R. García-Ramos, Is the corporate social responsibility–innovation link homogeneous?: looking for sustainable innovation in the Spanish context, *Corp. Soc. Responsib. Environ. Manag.* 27 (2020) 803–814, <https://doi.org/10.1002/csr.1845>.
- [10] G. García-Piqueres, R. García-Ramos, Complementarity between CSR dimensions and innovation: behaviour, objective or both? *Eur. Manag. J.* 40 (4) (2022) 475–489, <https://doi.org/10.1016/j.emj.2021.07.010>.
- [11] C. Bohlmann, L. Krumbholz, H. Zacher, The triple bottom line and organizational attractiveness ratings: the role of proenvironmental attitude, *Corp. Soc. Responsib. Environ. Manag.* 25 (2018) 912–919, <https://doi.org/10.1002/csr.1507>.
- [12] F.J. Forcadell, F. Úbeda, E. Aracil, Effects of environmental corporate social responsibility on innovativeness of Spanish industrial SMEs, *Technol. Forecast. Soc. Change* 162 (2021) 120355, <https://doi.org/10.1016/j.techfore.2020.120355>.
- [13] W. Li, W. Zhu, B. Wang, The impact of creating shared value strategy on corporate sustainable development: from resources perspective, *Corp. Soc. Responsib. Environ. Manag.* 30 (5) (2023) 2362–2384, <https://doi.org/10.1002/csr.24902376L1ETAL>.
- [14] N. Rahman, C. Post, Measurement issues in environmental corporate social responsibility (ECSR): toward a transparent, reliable, and construct valid instrument, *J. Bus. Ethics* 105 (3) (2012) 307–319, <https://doi.org/10.1007/s10551-011-0967-x>.
- [15] H. Fu, L. Ma, L. Wang, The contagion effect of corporate environmental responsibility in megaprojects: Analyzing underlying processes, *Sustain. Prod. Consum.* 40 (2023) 590–601, <https://doi.org/10.1016/j.spc.2023.07.025>.
- [16] R. Ruan, W. Chen, Z. Zhu, Linking environmental corporate social responsibility with green innovation performance: the mediating role of shared vision capability and the moderating role of resource slack, *Sustainability* 14 (24) (2022) 16943, <https://doi.org/10.3390/su142416943>.
- [17] C.-P. Martí-Ballester, Analysing the financial performance of sustainable development goals-themed mutual funds in China, *Sustain. Prod. Consum.* 27 (2021) 858–872, <https://doi.org/10.1016/j.spc.2021.02.011>.
- [18] C. Torrecillas, S. Fernández, Exports and outward FDI as drivers of eco-innovations. An analysis based on Spanish manufacturing firms, *J. Clean. Prod.* 349 (2022) 131243, <https://doi.org/10.1016/j.jclepro.2022.131243>.
- [19] A. McWilliams, D. Siegel, Corporate social responsibility: a theory of the firm perspective, *Acad. Manag. Rev.* 26 (1) (2001) 117–127, <https://doi.org/10.2307/259398>.
- [20] M.C. Branco, L.L. Rodrigues, Corporate social responsibility and resource-based perspectives, *J. Bus. Ethics* 69 (2) (2006) 111–132, <https://doi.org/10.1007/s10551-006-9071-z>.

- [21] Y. Armas-Cruz, E. Gil-Soto, J.R. Oreja-Rodríguez, Environmental management in SMEs: organizational and sectoral determinants in the context of an Outermost European Region, *J. Bus. Econ. Manag.* 18 (5) (2017) 935–953, <https://doi.org/10.3846/16111699.2017.1373375>.
- [22] V.H. Nguyen, N.H. Vu, Corporate environmental responsibility and innovation: empirical evidence from Vietnam, *Int. J. Emerg. Mark.* 18 (10) (2023) 4524–4544, <https://doi.org/10.1108/IJOEM-05-2021-0689>.
- [23] D. Antonioli, S. Mancinella, M. Mazzanti, Is environmental innovation embedded within high-performance organisational changes? The role of human resource management and complementarity in green business strategies, *Res. Pol.* 42 (2013) 975–982, <https://doi.org/10.1016/j.respol.2012.12.005>.
- [24] D. Antonioli, M. Gilli, M. Mazzanti, F. Nicolli, Backing environmental innovations through information technology adoption. Empirical analyses of innovation-related complementarity in firms, *Technol. Econ. Dev. Econ.* 24 (1) (2018) 141–163, <https://doi.org/10.3846/20294913.2015.1124151>.
- [25] J. Amores-Salvado, G. Martin-de Castro, J.E. Navas-López, The importance of the complementarity between environmental management systems and environmental innovation capabilities: a firm level approach to environmental and business performance benefits, *Technol. Forecast. Soc. Change* 96 (2015) 288–297, <https://doi.org/10.1016/j.techfore.2015.04.004>.
- [26] N. Darnall, G.J. Jolley, R. Handfield, Environmental Management systems and green supply management: complements for sustainability? *Bus. Strat. Environ.* 17 (2008) 30–45, <https://doi.org/10.1002/bse.557>.
- [27] S. Ozusaglam, E. Kesidou, C.Y. Wong, Performance effects of complementarity between environmental management systems and environmental technologies, *Int. J. Prod. Econ.* 197 (2018) 112–122, <https://doi.org/10.1016/j.ijpe.2017.12.026>.
- [28] T. García-Marco, F. Zouaghi, M. Sánchez, Do firms with different levels of environmental regulatory pressure behave differently regarding complementarity among innovation practices? *Bus. Strat. Environ.* 29 (4) (2020) 1684–1694, <https://doi.org/10.1002/bse.2461>.
- [29] Global Footprint Network, World footprint; do we fit on the planet? (2015) available at: www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/.
- [30] S.P. Chuang, S.J. Huang, The effect of environmental corporate social responsibility on environmental performance and business competitiveness: the mediation of green information technology capital, *J. Bus. Ethics* 150 (4) (2018) 991–1009, <https://doi.org/10.1007/s10551-016-3167-x>.
- [31] C. Yin, H. Ma, Y. Gong, Q. Chen, Y. Zhang, Environmental CSR and environmental citizenship behavior: the role of employees' environmental passion and empathy, *J. Clean. Prod.* 320 (2021) 128751, <https://doi.org/10.1016/j.jclepro.2021.128751>.
- [32] S. Choi, A. Ng, Environmental and economic dimensions of sustainability and price effects on consumer responses, *J. Bus. Ethics* 104 (2) (2011) 269–282, <https://doi.org/10.1007/s10551-011-0908-8>.
- [33] S. Ullah, N. Asma, Do firm-level sustainability targets drive environmental innovation? Insights from BRICS Economies, *J. Environ. Manag.* 294 (2021) 112754, <https://doi.org/10.1016/j.jenvman.2021.112754>.
- [34] D. Esty, M.E. Porter, Ranking national environmental regulation and performance: a leading indicator of future competitiveness? in: Michael E. Porter, Jeffrey D. Sachs, Peter K. Cornelius, John W. McArthur, Klaus Schwab (Eds.), *The Global Competitiveness Report 2001–2002* Oxford University Press, New York, 2002, pp. 78–101, 2002.
- [35] D. Schiessl, J.C. Korelo, A.P.M.S. Cherobim, Corporate social responsibility and the impact on economic value added: the role of environmental innovation, *Eur. Bus. Rev.* 34 (3) (2022) 396–410, <https://doi.org/10.1108/EBR-03-2021-0071>.
- [36] P. Bansal, K. Roth, Why companies go green: a model of ecological responsiveness, *Acad. Manag. J.* 43 (4) (2000) 717–736, <https://doi.org/10.2307/1556363>.
- [37] M. Chen, K. Wang, The combining and cooperative effects of carbon price and technological innovation on carbon emission reduction: evidence from China's industrial enterprises, *J. Environ. Manag.* 343 (2023) 118188, <https://doi.org/10.1016/j.jenvman.2023.118188>.
- [38] B. Blattel-Mink, Innovation towards sustainable economy—the integration of economy and ecology in companies, *Sustain. Dev.* 6 (2) (1998) 49–58, [https://doi.org/10.1002/\(SICI\)1099-1719\(199808\)6:2<49::AID-SD84>3.0.CO;2-I](https://doi.org/10.1002/(SICI)1099-1719(199808)6:2<49::AID-SD84>3.0.CO;2-I).
- [39] M. Wagner, Corporate social performance and innovation with high social benefits: a quantitative analysis, *J. Bus. Ethics* 94 (4) (2010) 581–594, <https://doi.org/10.1007/s10551-009-0339-y>.
- [40] P. Barney, Firms resources and sustained competitive advantage, *J. Manag.* 17 (1) (1991) 99–120, <https://doi.org/10.1177/014920639101700108>.
- [41] R. Hernández-Linares, M.C. López-Fernández, G. García-Piqueres, M. Pina e Cunha, A. Rego, How knowledge-based dynamic capabilities relate to firm performance: the mediating role of entrepreneurial orientation, *Rev. Manag. Sci.* (2023), <https://doi.org/10.1007/s11846-023-00691-4>.
- [42] M. Pérez-Pérez, A.M. Serrano-Bedia, M.C. Lopez-Fernandez, Opening manufacturing flexibility's black box: the unexplored role of internal flexibility, *J. Manuf. Technol. Manag.* 33 (3) (2022) 521–542, <https://doi.org/10.1108/JMTM-07-2021-0234>.
- [43] S. He, W. Zhao, J. Li, Y. Liu, Y. Wei, How environmental leadership shapes green innovation performance: a resource-based view, *Heliyon* 9 (2023) e17993, <https://doi.org/10.1016/j.heliyon.2023.e17993>.
- [44] S.L. Hart, A natural Resource-Based View of the firm, *Acad. Manag. Rev.* 20 (4) (1995) 986–1014, <http://www.jstor.org/stable/258963>.
- [45] M. Larrán-Jorge, J. Herrera-Madueño, D. Martínez-Martínez, M.P. Lechuga Sancho, Competitiveness and environmental performance in Spanish small and medium enterprises: is there a direct link? *J. Clean. Prod.* 101 (2015) 26–37, <https://doi.org/10.1016/j.jclepro.2015.04.016>.
- [46] J. Herrera-Madueño, M. Larrán-Jorge, M.P. Lechuga-Sancho, D. Martínez-Martínez, The evolution of corporate social responsibility in small and medium enterprises literature as a research discipline, *Rev. Eur. Econ. Empresa* 24 (2015) 117–128, <https://doi.org/10.1016/j.redee.2014.06.001>.
- [47] M.D. López-Gamero, J.F. Molina-Azorín, Environmental management and firm competitiveness: the joint analysis of external and internal elements, *Long. Range Plan.* 49 (6) (2016) 746–763, <https://doi.org/10.1016/j.lrp.2015.12.002>.
- [48] S.L. Hart, G. Dowell, A natural-resource-based view of the firm: fifteen years after, *J. Manag.* 37 (5) (2011) 1464–1479, <https://doi.org/10.1177/0149206310390219>.
- [49] C. Flores-Rivera, A.M. Serrano-Bedia, G. García-Piqueres, Motivations and outcomes of environmental corporate sustainability in family and non-family Mexican firms: the mediating role of eco-innovation strategy, *Corp. Soc. Responsib. Environ. Manag.* 31 (1) (2024) 357–374, <https://doi.org/10.1002/csr.2574>.
- [50] M.E. Porter, C. Van der Linde, Toward a new conception of the environment-competitiveness relationship, *J. Econ. Perspect.* 9 (4) (1995) 97–118, <https://doi.org/10.1257/jep.9.4.97>.
- [51] M. Claudy, M. Peterson, M. Pagell, He roles of sustainability orientation and market knowledge competence in new product development success, *J. Prod. Innovat. Manag.* 33 (S1) (2016) 72–85, <https://doi.org/10.1111/jpim.12343>.
- [52] C. Garcés-Ayerbe, J. Cañón-de-Francia, The relevance of complementarities in the study of the economic consequences of environmental proactivity: analysis of the moderating effect of innovation efforts, *Ecol. Econ.* 142 (2017) 21e30, <https://doi.org/10.1016/j.ecolecon.2017.06.022>.
- [53] S. Shao, Z. Hu, J. Cao, L. Yang, D. Guan, Environmental regulation and enterprise innovation: a review, *Bus. Strat. Environ.* 29 (3) (2020) 1465–1478, <https://doi.org/10.1002/bse.2446>.
- [54] S. Pekovic, A. Bouziri, Overcoming obstacles to innovation: can environmental management practices help? *Knowl. Manag. Res. Pract.* 21 (2) (2021) 345–360, <https://doi.org/10.1080/14778238.2021.1897486>.
- [55] M.A. Delmas, S. Pekovic, Sustainability and market conditions: the resource efficiency paradox, *Long. Range Plan.* 48 (2) (2015) 80–94, <https://doi.org/10.1016/j.lrp.2013.08.014>.
- [56] M. Delmas, Stakeholders and competitive advantage: the case of ISO 14001, *Prod. Oper. Manag.* 10 (3) (2001) 343–358, <https://doi.org/10.1111/j.1937-5956.2001.tb00379.x>.
- [57] S. Ren, D. He, T. Zhang, X. Chen, Symbolic reactions or substantive pro-environmental behaviour? An empirical study of corporate environmental performance under the government's environmental subsidy scheme, *Bus. Strat. Environ.* 28 (6) (2019) 1148–1165, <https://doi.org/10.1002/bse.2308>.
- [58] M.A. Delmas, S. Pekovic, Organizational configurations for sustainability and employee productivity: a qualitative comparative analysis approach, *Bus. Soc.* 57 (1) (2018) 216–251, <https://doi.org/10.1177/0007650317703648>.
- [59] B. Dostie, The impact of training on innovation, *Ind. Labor Relat. Rev.* 71 (1) (2018) 64–87, <https://doi.org/10.1177/0019793917701116>.
- [60] S.Y. Kim, H. Park, Corporate social responsibility as an organizational attractiveness for prospective public relations practitioners, *J. Bus. Ethics* 103 (4) (2011) 639–653, <https://doi.org/10.1007/s10551-011-0886-x>.

- [61] R. Chaudhary, A. Akhouri, Linking corporate social responsibility attributions and creativity: modeling work engagement as a mediator, *J. Clean. Prod.* 190 (2018) 809–821, <https://doi.org/10.1016/j.jclepro.2018.04.187>.
- [62] M.A. Delmas, S. Pekovic, Environmental standards and labor productivity: understanding the mechanisms that sustain sustainability, *J. Organ. Behav.* 34 (2) (2013) 230–252, <https://doi.org/10.1002/job.1827>.
- [63] O. Farooq, D.E. Rupp, M. Farooq, The multiple pathways through which internal and external corporate social responsibility influence organizational identification and multifoci outcomes: the moderating role of cultural and social orientations, *Acad. Manag. J.* 60 (3) (2017) 954–985, <https://doi.org/10.5465/amj.2014.0849>.
- [64] A. García-Pozo, J.L. Sánchez-Ollero, M. Ons-Cappa, Eco-innovation and economic crisis: a comparative analysis of environmental good practices and labour productivity in the Spanish hotel industry, *J. Clean. Prod.* 138 (2016) 131–138, <https://doi.org/10.1016/j.jclepro.2016.01.011G>.
- [65] D.E. Rupp, R. Shao, D.P. Skarlicki, E.L. Paddock, T.Y. Kim, T. Nadisic, Corporate social responsibility and employee engagement: the moderating role of CSR-specific relative autonomy and individualism, *J. Organ. Behav.* 39 (5) (2018) 559–579, <https://doi.org/10.1002/job.2282>.
- [66] X. Hu, Y. Tang, K. Motohashi, Varied university-industry knowledge transfer channels and product innovation performance in Guangdong manufacturing firms, *Knowl. Manag. Res. Pract.* (2020) 1–11, <https://doi.org/10.1080/14778238.2020.1747367>.
- [67] S. Pekovic, S. Rolland, H. Gatignon, Customer orientation and organizational innovation: the case of environmental management practices, *J. Bus. Ind. Market.* 31 (7) (2016) 835–848, <https://doi.org/10.1108/JBIM-11-2015-0228>.
- [68] N. Franco-Leal, R. Diaz-Carrion, A dynamic analysis of the role of entrepreneurial ecosystems in reducing innovation obstacles for startups, *J. Bus. Ventur. Insights* 14 (2020) e00192, <https://doi.org/10.1016/j.jbvi.2020.e00192OECDE>.
- [69] C.A. Geffen, S. Rothenberg, Suppliers and environmental innovation, *Int. J. Oper. Prod. Manag.* 20 (2) (2000) 166–186, <https://doi.org/10.1108/01443570010304242>.
- [70] M.C. Branco, L.L. Rodrigues, Corporate social responsibility and resource-based perspectives, *J. Bus. Ethics* 69 (2) (2006) 111–132, <https://doi.org/10.1007/s10551-006-9071-z>.
- [71] G. Ballot, F. Fakhfakh, F. Galia, A. Salter, The fateful triangle: complementarities in performance between product, process and organizational innovation in France and the UK, *Res. Pol.* 44 (1) (2015) 217–232, <https://doi.org/10.1016/j.respol.2014.07.003>.
- [72] S.A. Schweiger, T.R. Stettler, A. Baldauf, The complementarity of strategic orientations: a meta-analysis synthesis and theory extension, *Strat. Manag. J.* 40 (2019) 1822–1851, <https://doi.org/10.1002/smj.3042>.
- [73] P. Crifo, M.-A. Diaye, S. Pekovic, CSR related management practices and firm performance: an empirical analysis of the quantity–quality trade-off on French data, *International Journal of Production Economics, Corp. Soc. Responsib. Environ. Manag.* 25 (2016) 772–787, <https://doi.org/10.1016/j.ijpe.2014.12.019>.
- [74] D.J. Teece, Profiting from technological innovation: implications for integration, collaboration, licensing and public policy, *Res. Pol.* 15 (6) (1986) 285–305, [https://doi.org/10.1016/0048-7333\(86\)90027-2](https://doi.org/10.1016/0048-7333(86)90027-2).
- [75] F. Damanpour, R.M. Walker, C.N. Avellaneda, Combinative effects of innovation types and organizational performance: a longitudinal study of service organizations, *J. Manag. Stud.* 46 (2009) 650–675, <https://doi.org/10.1111/j.1467-6486.2008.00814.x>.
- [76] S. Magrizos, E. Apospori, M. Carrigan, R. Jones, Is CSR the panacea for SMEs? A study of socially responsible SMEs during economic crisis, *Eur. Manag. J.* (2020), <https://doi.org/10.1016/j.emj.2020.06.002> in press.
- [77] M.A. Mithani, Innovation and CSR—Do they go well together? *Long. Range Plan.* 50 (2017) 699–711, <https://doi.org/10.1016/j.lrp.2016.08.002>.
- [78] P. Christmann, Effects of “best practices” of environmental management on cost advantage: the role of complementarity assets, *Acad. Manag. J.* 43 (4) (2000) 663–680, <https://doi.org/10.2307/1556360>.
- [79] M.E. Porter, Reflections on a hypothesis: lessons for policy, research and corporate practice, Montreal, Canada, 28 June, available at: in: Presentation at the Porter Hypothesis at 20 Conference, 2010 www.sustainableprosperity.ca.
- [80] M.E. Porter, America’s green strategy, *Sci. Am.* 264 (4) (1991) 168.
- [81] D. Esty, M. Porter, Industrial ecology and competitiveness: strategic implications for the firm, *J. Ind. Ecol.* 2 (1) (1998) 35–43, <https://doi.org/10.1162/jiec.1998.2.1.35>.
- [82] S. Ambec, P. Lanoie, Does it pay to be green: a systematic review, *Acad. Manag. Perspect.* 22 (4) (2008) 45–62, <https://doi.org/10.5465/amp.2008.35590353>.
- [83] D. Archibugi, A. Filippetti, M. Frenz, Economic crisis and innovation: is destruction prevailing over accumulation? *Res. Pol.* 42 (2013) 303–314, <https://doi.org/10.1016/j.respol.2012.07.002>.
- [84] R. Belderbos, M. Carree, B. Diederen, B. Lokshin, R. Veugelers, Heterogeneity in R&D cooperation strategies, *Int. J. Ind. Organ.* 22 (8–9) (2004) 1237–1263, <https://doi.org/10.1016/j.ijindorg.2004.08.001>.
- [85] F. Schweitzer, C. Rau, O. Gassmann, E. Hende, Technologically reflective individuals as enablers of social innovation, *J. Prod. Innovat. Manag.* 32 (2015) 847–860, <https://doi.org/10.1111/jpim.12269>.
- [86] P. Mendi, Concentration of innovation investments along the business cycle, *J. Knowl. Econ.* (2023), <https://doi.org/10.1007/s13132-023-01267-z>.
- [87] O.D. Ovuakporie, K.G. Pillai, C. Wang, Y. Wei, Differential moderating effects of strategic and operational reconfiguration on the relationship between open innovation practices and innovation performance, *Res. Pol.* 50 (2021) 1041–1046, <https://doi.org/10.1016/j.respol.2020.104146>.
- [88] P. Milgrom, J. Roberts, The economics of modern manufacturing, technology strategy and organization, *Am. Econ. Rev.* 80 (1990) 511–528.
- [89] P. Milgrom, J. Roberts, Complementarities and fit: strategy, structure and organizational change in manufacturing, *J. Account. Econ.* 19 (1995) 179–208, [https://doi.org/10.1016/0165-4101\(94\)00382-F](https://doi.org/10.1016/0165-4101(94)00382-F).
- [90] J.H. Love, S. Roper, Organizing the innovation process: complementarities in innovation networking, *Ind. Innovat.* 16 (2009) 273–290.
- [91] P. Mohnen, L.-H. Roller, Complementarities in innovation policy, *Eur. Econ. Rev.* 9 (2005) 1431–1450, <https://doi.org/10.1016/j.euroecorev.2003.12.003>.
- [92] P. Criscuolo, K. Laursen, T. Reichstein, A. Salter, Winning combinations: search strategies and innovativeness in the UK, *Ind. Innovat.* 25 (2017) 115–143, <https://doi.org/10.1080/13662716.2017.1286462>.
- [93] E. Domínguez-Escrig, F.F. Mallén-Broch, R. Lapiedra-Alcamí, R. Chiva-Gómez, The influence of leaders’ stewardship behavior on innovation success: the mediating effect of radical innovation, *J. Bus. Ethics* 159 (3) (2019) 849–862, <https://doi.org/10.1007/s10551-018-3833-2>.
- [94] S. Haus-Reve, R.D. Fitjar, A. Rodríguez-Pose, Does combining different types of collaboration always benefit firms? Collaboration, complementarity and product innovation in Norway, *Res. Pol.* 48 (6) (2019) 1476–1486, <https://doi.org/10.1016/j.respol.2019.02.008>.
- [95] E.M. Gimenez-Fernandez, F.D. Sandulli, M. Bogers, Unpacking liabilities of newness smallness in innovative start-ups: investigating the differences in innovation performance between new and older small firms, *Res. Pol.* 49 (10) (2020) 104049, <https://doi.org/10.1016/j.respol.2020.104049>.
- [96] R. Foucart, C.Q. Li, The role of technology standards in product innovation: theory and evidence from UK manufacturing firms, *Res. Pol.* 50 (2) (2021) 104157, <https://doi.org/10.1016/j.respol.2020.104157>.
- [97] G. García-Piqueres, A.M. Serrano-Bedia, M.C. Lopez-Fernández, M. Pérez-Pérez, Relatedness in the adoption of different innovation types: product, process, organisational and commercial innovations, *Technol. Anal. Strat. Manag.* 32 (1) (2020) 44–57, <https://doi.org/10.1080/09537325.2019.1632822>.
- [98] K. Kim, J. Lee, C. Lee, Which innovation type is better for production efficiency? A comparison between product/service, process, organisational and marketing innovations using stochastic frontier and metafrontier analysis, *Technol. Anal. Strat. Manag.* 35 (1) (2023) 59–72, <https://doi.org/10.1080/09537325.2021.1965979>.
- [99] J.A. Schumpeter, *The Theory of Economic Development: an Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*, Harvard University Press, 1934.
- [100] Y. Amornkitvikai, P. Pholpirul, Business productivity and efficiency from aligning with sustainable development goals: empirical evidence from ASEAN manufacturing firms, *Bus. Strat. Dev.* 6 (2) (2023) 189–204, <https://doi.org/10.1002/bsd2.233>.
- [101] OECD, *The Measurement of Scientific and Technological Activities: Proposed guidelines for collecting and interpreting technological innovation data*, OCDE: Statistical Office of the European Communities (2005).
- [102] C. Hsiao, Benefits and limitations of panel data, *Econom. Rev.* 4 (1985) 121–174, <https://doi.org/10.1080/07474938508800078>.
- [103] C. Hsiao, *Analysis of Panel Data*, Cambridge University Press, Cambridge, 1986.

- [104] N.A. Klevmarcken, Panel studies: what can we learn from them? Introduction, *Eur. Econ. Rev.* 33 (1989) 523–529. [https://doi:10.1016/0014-2921\(89\)90131-1](https://doi:10.1016/0014-2921(89)90131-1).
- [105] B.H. Baltagi, in: *Econometric Analysis of Panel Data*, second ed., John Wiley & Sons, LTD, New York, 2002.
- [106] European Commission, Analysis associated with the roadmap to a resource efficient, Europe part II (2011) available at: http://ec.europa.eu/environment/resource_efficiency/pdf/working_paper_part2.pdf.
- [107] B.G. Tabachnick, L.S. Fidell, *Using Multivariate Statistics*, sixth ed., Pearson Education, Boston, 2012.
- [108] R.H. Myers, *Classical and Modern Regression with Applications*, second ed., PWS-Ken, Boston, 1990.
- [109] M. Gilli, S. Mancinelli, M. Mazzanti, Innovation complementarity and environmental productivity effects: reality or delusion? Evidence from the EU, *Ecol. Econ.* 103 (2014) 56–67, <https://doi.org/10.1016/j.ecolecon.2014.04.004>.
- [110] N. Hazarika, X. Zhang, Evolving theories of eco-innovation: a systematic review, *Sustain. Prod. Consum.* (2019) 64–78, <https://doi.org/10.1016/j.spc.2019.03.002>.
- [111] N.F. Arranz, M. Arroyabe, J.C. Fernandez de Arroyabe, Obstacles of innovation and institutional support in the cooperation agreements: the Spanish case, *Eur. J. Innovat. Manag.* 23 (4) (2020) 696–712, <https://doi.org/10.1108/EJIM-12-2018-0275>.