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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 to2014.[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 57,008[2] 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):

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

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**:

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

**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 (Adoption $\text{Innovation}_{it}$) as follows.

- Adoption innovation (Adoption $\text{Innovation}_{it}$) 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 market[4] 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:

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

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 $\text{Innovation}_{it}$, Market $\text{Innovation}_{it}$, Log transformation of Market $\text{Innovation}_{it}$, Firm $\text{Innovation}_{it}$, Log transformation of Firm $\text{Innovation}_{it}$.

| | Adoption $\text{Innovation}_{it}$ | Market $\text{Innovation}_{it}$ | Log transformation of Market $\text{Innovation}_{it}$ | Firm $\text{Innovation}_{it}$ | Log transformation of Firm $\text{Innovation}_{it}$ |
|---|---|---|---|---|---|
| $\text{Materials}_{it}$ | 3.7895 | 0.0485 | 0.0375 | 0.1443 | 0.1065 |
| | (0.1257)*** | (0.0071)*** | (0.0052)*** | (0.0088)*** | (0.0063)*** |
| $\text{Energy}_{it}$ | 3.8956 | 0.0794 | 0.0594 | 0.0887 | 0.0681 |
| | (0.1632)*** | (0.0089)*** | (0.0065)*** | (0.0109)*** | (0.0078)*** |
| $\text{Impact}_{it}$ | 3.4324 | 0.0663 | 0.0509 | 0.1084 | 0.0811 |
| | (0 0.0656)*** | (0.0041)*** | (0.0030)*** | (0.0050)*** | (0.0036)*** |
| $\text{Materials\&Energy}_{it}$ | 3.6094 | 0.0568 | 0.0437 | 0.1186 | 0.0888 |
| | (0.0684)*** | (0.0040)*** | (0.0029)*** | (0.0049)*** | (0.0035)*** |
| $\text{Materials\&Impact}_{it}$ | 3.6948 | 0.0725 | 0.0569 | 0.1342 | 0.1008 |
| | (0.1227)*** | (0.0073)*** | (0.0053)*** | (0.0089)*** | (0.0064)*** |
| $\text{Energy\&Impact}_{it}$ | 3.6218 | 0.0732 | 0.0562 | 0.1025 | 0.0782 |
| | (0.0968)*** | (0.0059)*** | (0.0043)*** | (0.0072)*** | (0.0052)*** |
| $\text{Materials\&Energy\&Impact}_{it}$ | 3.7111 | 0.0719 | 0.0564 | 0.1290 | 0.0985 |
| | (0.0498)*** | (0.0028)*** | (0.0020)*** | (0.0034)*** | (0 0.0024)*** |
| $\text{NoMaterials\&NoEnergy\&NoImpact}_{it}$ | 3.1381 | 0.0506 | 0.0387 | 0.1147 | 0.0850 |
| | (0.0433)*** | (0.0025)*** | (0.0018)*** | (0.0031)*** | (0.0022)*** |
| $\text{Internalrd}_{it}$ | −0.0931 | 0.0406 | 0.0322 | 0.0259 | 0.0217 |
| | (0.0365)** | (0.0024)*** | (0.0017)*** | (0.0029)*** | (0.0021)*** |
| $\text{Externalrd}_{it}$ | 0.0564 | 0.0125 | 0.0100 | −0.0042 | −0.0017 |
| | (0.0377) | (0.0024)*** | (0.0017)*** | (0.0029) | (0.0021) |
| $\text{Cooperation}_{it}$ | 0.0499 | 0.0070 | 0.0056 | 0.0032 | 0.0027 |
| | (0.0412) | (0.0026)*** | (0.0019)** | (0.0032) | (0.0023) |
| $\text{Group}_{it}$ | 0.1330 | −0.0021 | −0.0014 | 7.27e-06 | 0.0001 |
| | (0.0344)*** | (0.0025) | (0.0018) | (0.0030) | (0.0021) |
| $\text{Size}_{it}$ | 0.1662 | −0.0024 | −0.0016 | 0.0001 | 0.0003 |
| | (0.0108)*** | (0.0008)** | (0.0005)** | (0.0009) | (0.0006) |
| Sector dummies | Yes | Yes | Yes | Yes | Yes |
| Time dummies | Yes | Yes | Yes | Yes | Yes |
| Constant | −2.2753 | 0.0178 | 0.0126 | −0.0142 | −0.0110 |
| | (0.1444)*** | (0.0111) | (0.0082) | (0.0132) | (0.0094) |
| σ | 1.2245 | | | | |
| | (0 0.0215) | | | | |
| ρ | 0.5999 | | | | |
| | (0.0084) | | | | |
| Sigma | | 0.1134 | 0.0844 | 0.1287 | 0.0930 |
| | | (0.0010)*** | (0.0007)*** | (0 0.0012) | (0.0009) |
| Log Likelihood | −15764.147 | 18764.216 | 36812.993 | 7093.2077 | 26290.541 |
| Wald $\text{chi}^2$ | 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) ≥ 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) ≥ f(101) + f(001) | 1.29 | 0.2569 | 034 | 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) ≥ 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) ≥ 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) ≥ 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) ≥ 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 $p < 0.1$.

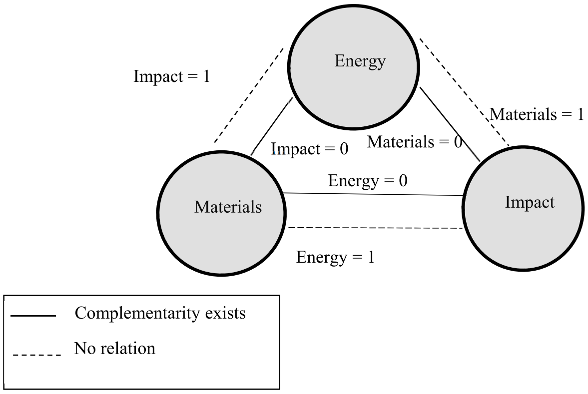


**Fig. 1.** Complementarities among environmental corporate social responsibility practices for Adoption Innovation.
Source: Authors' own elaboration based on Ballot et al. (2015)

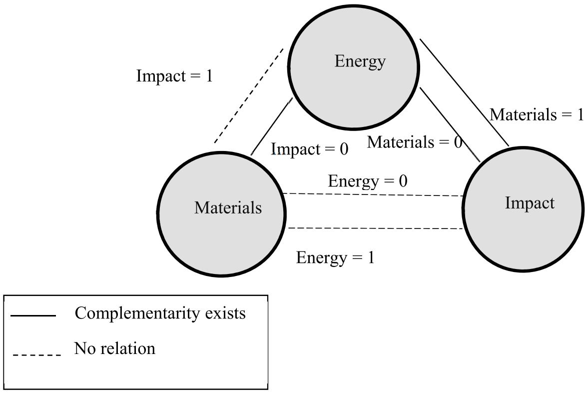


**Fig. 2.** Complementarities among environmental corporate social responsibility practices for Market Innovation.

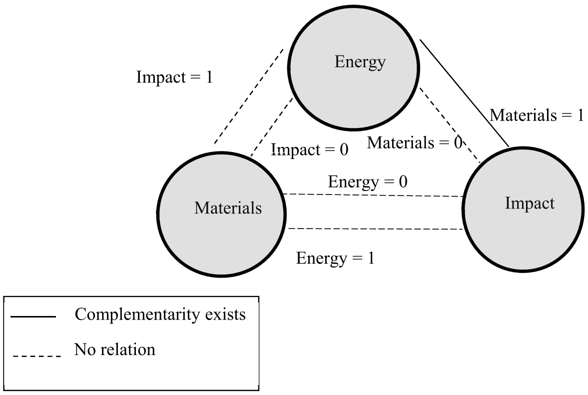


**Fig. 3.** Complementarities among environmental corporate social responsibility practices for Firm Innovation.

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 Innovation$_{it}$** | | | **Not present** | H2 accepted |
| | | **Not present** | | H2 accepted |
| | **Not present** | | | H2 accepted |
| | | | **Present** | H2 rejected |
| | | **Present** | | H2 rejected |
| | **Present** | | | H2 rejected |
| **Market Innovation$_{it}$** | | | **Not present** | H2 accepted |
| | **Present** | | | H2 accepted |
| | **Not present** | | | H2 accepted |
| | | | **Present** | H2 rejected |
| | | **Not present** | | H2 rejected |
| | | **Present** | | H2 rejected |
| **Firm Innovation$_{it}$** | **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 ECRS 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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