

The role of SMEs' Green Business Models in the transition to a low-carbon economy: differences in their design and degree of adoption stemming from business size

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Abstract:

The purpose of this paper is to analyze how Green Business Models (BMs) established by small and medium enterprises (SMEs) can incorporate product and process decarbonization in their components (value proposition, creation and capture) and to what extent this incorporation is affected by SME size. We use a database comprising 1,161 observations of SMEs, 466 in 2014 and 695 in 2016. The results show that SMEs' value propositions give an intermediate valuation to both legally required and voluntary reduction of environmental impact, irrespective of SME size and the year analyzed. Regarding value creation, SMEs adopt practically no environmental practices, and there are significant differences according to size, with more difficulties than advantages stemming from small size. The study also shows that such environmental practices are not effective in reducing carbon. This diagnosis indicates that SMEs need help from the administration if they are to play a key role in the process of transformation toward a low-carbon economy. Legislative actions involving harsher environmental protection measures might help shape value propositions that place greater importance on reducing environmental impact, whereas training actions on available environmental techniques, promotion of research on how to adapt such techniques to SMEs and the development of specific practices for SMEs might enhance environmental value creation and capture in their BMs.

Keywords: Green Business Models, Decarbonization, SMEs, Size.

1. Introduction

This study falls within the framework of the Great Climate Challenge [1,2]. It analyzes how small and medium enterprises (SMEs) include decarbonization in their business models (BMs) and how their size affects the design and implementation of such models.

Although there have been many initiatives aiming to cut greenhouse gas emissions and hold back the negative consequences of global warming since the Rio Summit (1992) and the Kyoto Protocol (1997), CO₂ emissions have continued to increase year after year [3]. The most optimistic estimates indicate that more than half the level of greenhouse gases that would generate global warming in excess of 2 °C above the preindustrial level [4] have already been emitted and are accumulating in the atmosphere. In an attempt to stop this process, a large proportion of the international community signed the Paris Agreement in 2015 to reduce emissions during the period from 2050 to 2100. This is an ambitious commitment in which energy efficiency and early reductions of CO₂ emissions are key [5], especially in businesses [6,7].

In view of the role of businesses in the sustainable development of society [8,9], it seems surprising that the environmental strategy literature started to cover decarbonization so late [10,11]. Undoubtedly, through some areas such as institutional theory [12,13], stakeholder theory [14-16] or resource-based theory [17-19], knowledge has increased regarding some of the institutional and organizational factors that explain the level of adoption of environmental strategies. However, given the evidence on the constant rise in levels of anthropogenic CO₂ [6,20], these approaches seem to have been insufficient for promoting the transition toward a low-carbon economy [21]. In this situation, BMs, understood as the set of activities and processes carried out by firms when defining the value proposition, creation and capture for their stakeholders [22-24], might be an appropriate tool to achieve this transition [25].

The few studies that have specifically analyzed the topic of BMs and decarbonization focus on the energy sector [25-28]. Others, falling under the literature related to Green BMs [29,30] and Sustainable BMs [23,31,32], cover different environmental aspects associated with BMs but without focusing explicitly on decarbonization. In addition, although SMEs account for about 99% of the business fabric of EU countries [33] and are jointly responsible for a large volume of the environmental impact [34], which many authors set at about 70%¹ [35-37], most studies

¹ This figure has attained a mythical status, albeit unjustifiably, because national economic statistics on SMEs do not usually include data on emissions, so it is debatable whether SMEs' contribution to contamination can be calculated [34]. However, we agree with Hillary that given the large number of SMEs in the main economies, collectively, they have a great environmental impact [34].

focus on large corporations, while the study of SMEs is limited to the analysis of certain cases with a proactive attitude [31,38].

In this context, the goal of this study is to analyze how SMEs' BMs can incorporate product and process decarbonization in their components (value proposition, creation and capture) and to what extent this incorporation is taking place in SMEs of different sizes.

From a theoretical point of view, our contribution covers three aspects. First, in the literature on Green BMs and Sustainable BMs, we include the literature on decarbonization, an important topic which nevertheless is not explicit in most of this literature [23,32,39], with a few exceptions in the energy sector [25,40]. Second, we focus on SMEs that, in general, have been understudied, except for some case studies showing selection bias toward environmental proactivity [28,41,42]. Third, we search for differences in the degree of incorporation of decarbonization in SMEs' Green BMs depending on their size because both the traditional literature on environmental strategy and that on BMs point to different barriers and enablers for the development of environmental strategies and BMs depending on size [43,44].

From a strictly empirical point of view, our paper has certain strengths: 1) It is a quantitative exploratory analysis [45], although the literature mostly comprises case studies [7,28]; 2) we work with a database with information on 466 SMEs in 2014 and 695 in 2016, without establishing any bias toward the environmental proactivity that can be found in many previous studies [42,43]; 3) we present a multisector study, in contrast to studies that focus on a single sector [25,46,47]; and 4) we work in a three-year time frame because innovation processes in BMs are long and have many complex effects on business performance [48].

The paper is structured as follows. In section 2, we analyze how businesses have included environmental matters in their strategies. We then study the elements that make up Green BMs, how decarbonization is included in their products and processes, and the influence of size on this configuration. Section 3 describes the sample of businesses and the methodology used. We then explain the results of our analysis, draw the main conclusions and describe their implications for business management and public policy.

Conceptualization of BMs: their role in environmental decarbonization.

2.1. Delimitation and definition of BMs

BMs have been generating increasing interest among managers and researchers since the 1990s with the growth of dotcom companies [49]. Intuitively, a BM could be defined as a description of an organization and of how it functions to meet its goals—profitability, growth, social impact, etc. [50]. However, going beyond that intuitive idea, there is still no consensus on how to define the BM concept [45,50-53]. The multidimensional nature of BMs makes it

difficult to build a theory around them [52,54]. Their definition and conceptualization have varied depending on the purpose of the research and the theoretical approach adopted by researchers [53]. It is therefore important for researchers to give a precise definition of the BM concept used in their research [52].

In this study, of the three possible interpretations that researchers have given to BMs—*attributes of a real firm, cognitive or linguistic outline, or conceptual representation* [50]—we use the most specific concept possible, that is, the attributes of a real firm. We consider BMs to be the set of activities and processes carried out by a firm [31] that allow it to define how to propose, create and capture value for its stakeholders [22-24]. More specifically, we consider that an organization's BM reflects the strategy adopted and comprises the set of choices made by the firm based on its strategy and the consequences of the latter [24]. We therefore place the BM between the strategy level and the operational level. This idea is shared by a large number of authors, both theoretically [22,24,55] and empirically [42,56].

BMs themselves may also be subject to innovation [48,57]. When creating or adapting a BM, alternatives to current ways of doing business have to be explored, and it is important to understand how firms can meet their customers' needs in different ways. Executives have to learn to question existing models and to act entrepreneurially in order to develop new delivery mechanisms [58]. The search for sustainability is starting to transform the way in which firms compete, so they may be forced to change the way they see products, technologies, processes and BMs [58].

2.2 Integrating environmental aspects associated with climate change in BMs

Integrating climate change in business strategies is one of the main challenges faced by firms today [2]. They are under increasing pressure from governments and stakeholders to reduce their CO₂ emissions and thus mitigate climate change [11]. But, even though there is no alternative to sustainable development [58], firms have not included the management of their CO₂ emissions in their strategies [1].

Traditionally, institutional theory [12,13], stakeholder theory [14-16] and resource-based theory [17-19,59] have helped improve knowledge of the determinants of environmental strategies and of the institutional and organizational factors that broadly explain such strategies. However, such studies have not dealt specifically with the incorporation of climate change in environmental strategies. It was only in the second half of the first decade of the 21st century that a large number of studies started to appear focusing on climate change strategy and carbon reduction [60-63]. Since then, interest has grown, and in recent years, many works have analyzed a range of subjects, among them carbon reduction strategies and practices [2,11,64,65]; barriers to and enablers of such strategies [66,67]; and the effects that carbon

reduction strategies and practices have on economic and environmental performance [6,68]. Although much of this literature analyzes business size, the results are not clear. For example, regarding the relation between carbon reduction strategies and business size, some authors find no significant differences between firms of different size [65], while others state that in large enterprises, the degree of adoption is greater, but there is no clear correspondence with CO₂ emissions [2,11].

Although this literature has improved knowledge regarding the determinants of environmental strategy, strategic vision seems insufficient to achieve the transformation that organizations need for the transition to a low-carbon economy [21,38]. More overarching approaches are necessary to assess carbon reduction strategies and their consequences, and BMs may be an appropriate tool for this. The formulation of Green BMs forces managers to reflect on how firms can propose, create and capture environmental value in their processes, products and services [23,30,32].

According to Mangelsdorf [21], the process of decarbonization at a normal rate would take 50 years, which is too long if we are to reach the environmental goal of limiting global warming to 2 °C. However, BMs can speed up this process [21,25,69]. Some recent studies have analyzed the role that BMs can play in processes to transform societies into low-carbon economies [25,40]. They consider three possible roles: 1) BMs form part of today's socio-technical regime and are based on the standard modus operandi in the sector. This role helps them to maintain links with other related sectors, so in this case, BMs act by strengthening current regimes and BMs and establishing barriers (lock-in) for new BMs, in our case, Green BMs. 2) Existing or new BMs are also devices for marketing technological innovations, making it possible to demonstrate the value of new technologies, facilitating the expression of expectations among different agents and allowing more technological links to be created among more agents, thus creating networks of value around the technological innovation. 3) BMs themselves may be subject to innovation, irrespective of the technologies involved, and may change the modus operandi in a sector. This happens when new methods of creating and capturing value have reached a critical mass of agents in a new value network.

The last two of these roles are especially useful for SMEs that want to transition toward a low-carbon economy because they help them overcome the barriers imposed by the BMs of established firms. The literature describes cases such as that of NativeEnergy, an SME in the renewable energy sector with 15 workers at the time of the study, which, thanks to an innovation in its BM, was able to become the leader in its sector, with activity throughout the US and in Alaskan native villages [41]. Furthermore, innovation in BMs may be a good option for SMEs to include responsible innovation in their firms rather than other more costly and complex types of innovation [70]. However, in spite of the potential for making climate change

and carbon management a main pillar of their BMs, the current degree of integration in firms is not known [1], and this is especially true for SMEs. There have been few studies on BMs and decarbonization in SMEs, and the ones that exist focus on the energy sector [28,41].

On the other hand, more general literature on Green BMs and Sustainable BMs² covers more sectors but does not deal explicitly with decarbonization. In many cases, studies are theoretical, and most of the empirical studies focus on large corporations [31,71]. Therefore, the study of SMEs is limited to the analysis of certain cases, but again, there is a selection bias toward environmental proactivity [42,72].

Our study aims to fill this gap that has been detected in the literature by analyzing how SMEs include environmental aspects in their Green BMs and to what extent these facilitate decarbonization. We define Green BMs by extrapolating the structure of BMs to the environment in three components: value proposition, creation and capture for the firm and for its stakeholders [22,24]. This extrapolation has already been performed by other authors, such as Bocken et al. [23], in the environmental and social area. By means of an exploratory study, we quantify the degree of integration being achieved from a multisector point of view and taking into account the effects of SME size. We include this variable in our analysis because size may have an ambivalent role, either promoting or hindering environmental efforts [73], and because among SMEs, there is great diversity [43] that makes it necessary to break down the study by size.

2.2.1. Green BMs: Environmental value proposition

The value proposition of a BM is related to the firm's strategic positioning. It defines what it will deliver to its customers, what characteristics customers will be prepared to pay for and the firm's basic approach to obtaining competitive advantages [22]. From an environmental point of view, the value proposition in a BM should provide measurable ecological and social value in relation to the economic value [32,38]. When defining it, firms should consider the environmental needs of the firm's stakeholders because these should determine the strategic drivers for corporate sustainability, emphasizing the main corporate goals for adopting win-win environmental solutions [74].

However, the analysis of stakeholder needs is subject to the perception of firms' managers. This means we may find firms that are subject to the same institutional pressure but that react to it differently [12,75]. Factors such as the company culture or idiosyncrasy, the internal organization of departments and the sources of information they use [12], as well as the

² The main difference between Green and Sustainable BMs is that the former focus on environmental aspects and the latter include social aspects. In this study, we talk about Green BMs because we focus exclusively on environmental aspects.

degree of environmental maturity [76] or personal values and beliefs [42,43], may lead firms to perceive, interpret and respond differently to stakeholders' needs/pressure. Additionally, it should be remembered that not all firms are subject to the same pressures. Market leaders, multinationals or firms that historically were less environmentally friendly may be subject to greater pressure [12].

Differences in stakeholder pressure and different interpretations of such pressure will lead to different environmental strategies and also, therefore, to different value propositions in BMs. There will be firms that only comply with sector regulations and others that want to keep their stakeholders happy and thus consider environmental strategies that allow them to reduce the environmental impact of their operations beyond regulatory requirements [19].

It is therefore in the value proposition of Green BMs that managers will express their commitment to the environment. There will be Green BMs in which the value proposition focuses on complying with compulsory regulations, but there will be others that go further than this, aiming to voluntarily reduce the environmental impact of their products and activities. We believe that it will be in the latter that Green BMs will be developed in which value creation and capture will be more committed to decarbonization.

With respect to size, we believe it may affect the definition of the value proposition of SMEs' Green BMs because such firms are less visible than large ones and are therefore subject to less external pressure [73]; also, smaller (and micro) SMEs may think it is not necessary to comply with regulations ([77]. Many SMEs see requirements to include environmental aspects in their strategy as a cost that cannot be transferred to their customers in terms of added profit, and few of them consider that managing such aspects will allow them to achieve a competitive advantage [78].

In addition, owner/managers of SMEs often enjoy greater decision-making freedom than the managers of large corporations. Their personal responsibility and their motivations therefore have a greater influence on the strategic management of the business [79] and may lead them to be more committed to climate change [43]. Because size, therefore, has a controversial role, we will analyze its influence on the definition of value propositions in Green BMs.

2.2.2 Green BMs: Creation and delivery of environmental value

The creation and delivery of value make it necessary to establish how the firm will compete to put into practice its value proposition [22,74]. This is the heart of any business model [23] and includes the resources, activities and key processes, as well as links with suppliers, partners and clients, that will allow the value proposition to be implemented [22,23]. When the

creation and delivery of value are designed, the value proposition and capture must be borne in mind [22].

In our case, Green BMs must define their creation and delivery of environmental value bearing in mind the proposition and capture of environmental value. The value proposition must improve the firm's environmental impact (voluntarily or because it is required by law). The capture of value, to be explained in the next section, aims to reduce CO₂ emissions in order to achieve product and process decarbonization in Green BMs. Therefore, in view of this value proposition and capture, the creation and delivery of environmental value must be carried out using the resources, activities and processes that make it possible to reduce environmental impact by decarbonizing products and processes.

We identify nine voluntary practices, which go beyond end-of-pipe practices and really allow the creation and delivery of environmental value. This is not a full list of all proactive environmental management practices, but all of them are relevant for the environmental management of products and processes and/or firms' energy management. End-of-pipe technologies are not included because we consider that they do not generate value but, rather, may amount to an unproductive cost for firms [80]. We also consider that firms in which prevention technologies carry greater weight than in those that only have end-of-pipe technologies will be more successful in reducing their environmental impact [80]. Below is a description of how these nine practices can help generate environmental value in the transition toward a low-carbon economy.

1. Energy and environmental audits. Audits are useful tools for helping firms to better understand their environmental behavior. A full audit can help identify potential energy savings of 15-30% in an SME, whatever its economic activity or number of employees [81]. The slogan "If you can't measure it, you can't manage it" can be applied to resources and costs as well as to carbon emissions. It therefore seems important to identify and manage emissions of carbon and other contaminants for both companies in regulated sectors that are legally required to quantify their emissions and those in non-regulated sectors that voluntarily calculate and publish their carbon emissions [82].

2-3. Product life cycle and ecological design. These two techniques that are used in sustainable manufacturing allow any product or process to be analyzed in terms of improved environmental performance, quality and competitiveness, while also minimizing manufacturing costs [83]. Eco-design is very important because 80% of product sustainability impacts are decided on during the product design and development stage [83]. Life cycle analysis is a key tool to help guarantee sustainability by assessing the environmental impact of product designs [84] and is used to analyze the carbon footprint of SMEs [85].

4. Eco-labeling. Eco-labeling (also known as environmental labeling or carbon labeling) is another environmental practice, of a voluntary nature, that has received significant interest worldwide [86,87]. An eco-label identifies a proven environmental distinction of a product or service within a specific product or service category. Eco-labels are therefore an explicit way of showing the environmental quality of products [88]. From the point of view of a company, voluntary eco-labeling programs can set it apart from its competitors and offer flexibility to take on commitments to improve its environmental performance beyond what is required by law [88].

Eco-labeling is being applied in a variety of sectors such as construction, agriculture, fashion, tourism and consumer products [87,89-91]. However, not all eco-labels are necessarily directly related to CO₂ emission reduction. For example, in the tourism sector, of the 128 eco-labels studied by Gössling and Buckley [90], 51 do not consider energy saving or greenhouse gas emissions, and in the fishing sector, decarbonization of fish products is rarely covered by eco-labels [89].

5. Best available techniques (BATs) for attaining lower consumption of resources and/or environmental impact. Depending on the characteristics of the different carbon-intensive industrial processes, new technologies can reduce CO₂ emissions. Because of the wide range of industries and industrial processes, there is also a wide range of possible technological improvements [65]. In this context, the identification, evaluation and selection of the best available techniques (BATs) to improve critical environmental points in production processes can achieve very relevant environmental improvements [92]. Moreover, analysis of BATs can also be applied together with other environmental practices, thus enhancing their energy efficiency. For example, in cogeneration and trigeneration, the technologies available for combined production can help increase the degree of emission reduction [93].

6. Recycling, reuse and/or valorization of sub-products and waste products. Recycling is defined as a method for recovering resources that involves the collection and processing of waste products to be used as raw materials in the production of the same or a similar product. The EU's waste strategy makes a distinction between reuse and recycling. Reuse means using waste as raw material in a different process with no structural change, and recycling refers to structural changes in the materials within the same process [94]. These complex processes are used in many industries, such as construction [95] and electronics [96], and allow the firms using them to be more environmentally friendly. Burke and Gaughran [97] indicate that 83% of Irish SMEs are involved in waste minimization and recycling.

7. Waste and recycled materials for generating energy. Unprecedented, cheap technological progress over recent centuries has increased waste generation. Furthermore, waste has

increased not only in quantity but also in heterogeneity and complexity and in the creation of new, sometimes hazardous, substances (plastics, dyes, paints, drugs, electronic components, etc.) [98].

Waste incineration helps protect the environment by preventing dangerous organic waste from reaching it. Additionally, low-carbon energy can be generated from waste, thus reducing greenhouse gas emissions [98]. Attempts are being made today to recover materials from waste produced in the actual process of power generation [98], thus reducing CO₂ emissions. Furthermore, the use of cotton waste might be a viable, cheap and environmentally friendly alternative for producing thermal energy [99].

8. Cogeneration and trigeneration. Cogeneration systems, which are combined systems for producing both heat and power, are known to save a considerable amount of power in comparison with the separate production of the same amount of heat (from conventional combustion generators) and power (from conventional power stations) [100]. Trigeneration systems are based on combined heat and power systems coupled with absorption coolers that use cogeneration. Therefore, the heat that would be wasted during the summer because of a lack of demand can be effectively exploited to produce power for cooling, for use in air conditioning systems. As a consequence of their improved energy performance, cogeneration and trigeneration systems can also bring important environmental benefits in terms of greenhouse gas reduction [93,101,102].

9. Adoption of renewable energies (wind, photovoltaic, geothermal, solar-thermal energy). Renewable energy sources, also called alternative energy sources, are resources that can be repeatedly used to produce energy, such as solar, wind or geothermal energy. Renewable energy technologies are considered clean and, when used optimally, they minimize environmental impact, produce minimal secondary waste and are sustainable from the point of view of current and future social and economic needs [103]. Therefore, replacing fossil fuels with renewable sources of energy reduces the environmental impact and the CO₂ emitted into the atmosphere.

The inclusion of these practices in Green BMs should generate and deliver environmental value so that the environmental proposition can be put into practice (complying with environmental requirements and reducing environmental impact) while capturing the value (reduction of CO₂ emissions) that Green BMs seek. We consider that the more such practices are included in Green BMs, the more environmental value they will generate and capture.

In addition, when these techniques are applied, firms should be innovative and critical of the systems they are using so that they can identify any uncaptured value. The identification of any uncaptured (superfluous, absent, lost or destroyed) value may trigger the discovery of new

opportunities for creating, delivering and capturing value and may lead to innovation in sustainable BMs [49]. This approach will therefore facilitate innovation in Green BMs and increase the possibility of stepping up decarbonization of SMEs' products and processes.

Business size also affects the creation and delivery of environmental value because it may hinder or facilitate the number of practices that businesses include in their Green BMs. It is more difficult for SMEs to consider and adopt several strategic options in response to climate change than large corporations [11], mostly due to lack of knowledge and of human and financial resources [2] and because of their dependence in most cases on a small number of clients. However, small enterprises are more flexible and less tied to formalities so they can adapt to change faster [73]. Furthermore, their owner-managers are freer to change the business's strategic direction [79], which may lead them to a greater commitment to climate change [43] and may encourage them to adopt a larger number of environmental practices. The influence of size in the adoption of climate change strategies is therefore not clear. Weinhofer and Hoffmann [11] found that large corporations adopt more strategies against climate change, while Cadez and Czerny [65] only found evidence in favor of large corporations in one of the six climate change strategies they studied.

We shall therefore explore, on the one hand, the most common practices for creating and delivering environmental value in Green BMs and their most frequent combinations, and on the other hand, if there are differences stemming from business size in both the types of environmental practices and their combinations.

2.2.3 Green BMs: Capturing environmental value by increasing carbon productivity

Value proposition, creation and delivery do not guarantee business success if the firm does not capture value [22], or, as some people put it, does not appropriate value [104,105]. The relation between the dimensions of value creation and capture/appropriation is therefore key in BMs [106].

The traditional literature on BMs points to elements of cost and revenue structure for measuring value capture [55,107], while the literature on Green and Sustainable BMs includes other forms of non-monetary value capture [23,72]. This difference is because, in the context of corporate sustainability, economic results are insufficient for ensuring sustainable value capture [74] because environmental and social value must also be included [49].

In our study, which analyzes if the Green BMs of SMEs are helping to achieve decarbonization of the economy, we will measure value capture by quantifying their CO₂ emissions. This measure covers environmental value because it quantifies, with the aim of reducing, the main greenhouse gas. In addition, this way of seeing value capture can be said to be present in the

three archetypes of sustainable technological BMs identified by Bocken et al. [23], who talk about “*minimized environmental footprint*,” “*reduced footprint*” and “*reducing emissions associated with burning fossil fuels*.” The Green BMs of SMEs should try to generate value with low CO₂ emissions and, if possible, to reduce such emissions over time.

Because the possible financial benefits of saving and the efficiency of resources resulting from applying environmental improvements are usually smaller in SMEs [73], again, we analyze how size affects the stage of environmental value capture.

3. Data and variables

For our exploratory study, we used a database with economic and environmental microdata from 466 SMEs in 2014 and 695 in 2016 (1,161 observations). Data was obtained from the *GIS* survey [108]. This is the largest survey of business innovation in the northwest of Spain. Coordinated by the Galician Innovation Agency (GAIN), this annual online questionnaire provides a unique opportunity because it allows us to analyze in depth the two areas of interest in our research: sustainable BM pillars and decarbonization.

Regarding the submission process, the contact person was always a top-level informant (manufacturing manager, industrial/operations director or CEO, depending on the size of each company) with a global perspective and knowledge (or access to information) about the industrial and business requirements. According to Phillips [109], top-level informants tend to be more reliable sources of information than lower-level employees. Furthermore, random phone calls to non-response companies were made, and no specific pattern was evident in these cases or in the reasons given for non-response. There is no evidence, therefore, that responses were only received from a specific type of company, and it is not necessary to consider the non-response bias that may occur in online surveys. Similarly, comparison of early and late responses [110] found no statistically significant differences in any of the study variables. Table 1 shows the distribution of firms by size (employees), turnover and sector.

Table 1. Distribution of SMEs by size, turnover and sector

Characteristics	2014 (%)	2016 (%)
Size		
Micro: ≤ 10 workers	8	7
Small: 11-50 workers	77	73
Medium: 51-250 workers	15	20
Turnover		
2-10 €M.	41	39
11-50 €M.	10	12
51-100 €M.	2	1
Over 100 €M.	27	28
Sector		
High and medium-high technology	18	15
Low and medium-low technology	82	85

Regarding the environmental value proposition, we distinguish between legally required or voluntary reduction of environmental impact. For the former, we built a categorical variable that assesses the importance placed by the SME on the degree of compliance with environmental requirements as a goal of its innovation activity. Similarly, for the latter, we asked about the importance of obtaining a lower environmental impact. In both cases, the valuation was rated on a 3-point Likert scale, with 1 meaning little importance, 2 meaning medium important and 3 meaning high importance.

To measure value creation, we asked about the use of nine voluntary practices that go beyond end-of-pipe practices and really allow for the creation and delivery of environmental value, helping to generate environmental value for a transition toward a low-carbon economy: (i) energy and environmental audits, (ii) life cycle analysis, (iii) ecological design, (iv) eco-labeling, (v) best available techniques, (vi) valorization of sub-products and waste, (vii) use of waste to generate power, (viii) cogeneration and trigeneration, and finally, (ix) use of renewable energies. We then built a continuous variable with values from 0 to 9 indicating the number of practices used by each firm.

Finally, to explore if Green BMs are helping to achieve decarbonization of the economy, the value capture of a Green BM was measured by the inverse of one of the most common indicators in the fight against climate change and the upcoming *Circular Economy monitoring framework: Carbon intensity*: the ratio of CO₂ emissions to revenue [111-114]. This measure (eq. 1) is used by researchers and institutions as a policy instrument (e.g., national targets and emission pledges) for valuing emission reduction potential and progress on decarbonization at the sector level [115,116]. The *Green Growth initiative* in the OECD, for example, includes this ratio as an environmental decoupling indicator [117].

$$Carbon\ Prod = \frac{Total\ Revenue}{\sum_{x1}^{x5} CO2\ emissions} \text{ (eq. 1)}$$

where the subscript x identifies the different energy sources in each SME, measured as CO2eq in €: electricity, natural gas, fuel oil, gas oil and GLP (butane and propane).

To measure the size of the SMEs, we used the number of employees, distinguishing between micro (up to 10 employees), small (from 11 to 50 employees) and medium (from 51 to 250 employees) enterprises. Table 2 shows the main descriptive statistics for these variables for 2014 and 2016.

Table 2. The main descriptive statistics

	2014					2016				
	N	Mean	STD	Min.	Max.	N	Mean	STD	Min.	Max.
Legal proposition	323	2.06	0.78	1	3	485	2.04	0.74	1	3
Voluntary proposition	320	1.95	0.76	1	3	475	1.95	0.73	1	3
Value creation	466	1.1	1.52	0	9	695	1.25	1.53	0	7
Value capture	365	52.9	129.1	0.04	1592.1	557	62.87	133.9	0.10	1443.8
Size	466	2.07	0.46	1	3	695	2.13	0.51	1	3

4. Results

With the information from this database, we performed an exploratory analysis to test how the SMEs include product and process decarbonization in their components (value proposition, creation and capture); to what extent this inclusion depends on the size of the SME, because the literature points to several barriers and enablers for developing environmental strategies and BMs that depend on size [43,44]; and, finally, how defining BMs becomes a long process with many complex effects for the firm's performance. We also studied the evolution over time of the inclusion of decarbonization in the value proposition, creation and capture, and the effect of size. In both cases, we used the non-parametric Kruskal-Wallis test.

4.1 Green BMs: Value proposition

SMEs place medium importance in their value proposition on compliance with both the legally required and voluntary reduction of the environmental impact of products and services, with medium values in 2016 of 2.04 and 1.95, respectively. Regarding how this inclusion takes place in terms of business size (Table 3), we observed no significant differences between the three types of enterprise (micro, small and medium) in the definition of the environmental value proposition, the importance placed on innovation for legal compliance or the reduction of the voluntary environmental impact.

Table 3. Value proposition: differences by size

	Size	Value proposition	
		Legal	Voluntary
Medium values	Micro	2.38	2.12
	Small	2.02	1.93
	Medium	2.03	1.99
Kruskal-Wallis test	Chi-squared	5.295	2.0666
	Asymptotic sig.	0.071	0.356

In addition, the analysis of evolution over time shows that there were no important changes in the definition of the value proposition by the SMEs after 2014. Table 4 shows that there are no significant differences either globally or in terms of SME size.

Table 4. Value proposition: evolution over time, globally and by size

		All SMEs		Micro		Small		Medium	
		Legal	Voluntary	Legal	Voluntary	Legal	Voluntary	Legal	Voluntary
Average values	2014	2.06	1.95	1.95	1.83	2.07	1.95	2.02	2,02
	2016	2.04	1.95	2.38	2.12	2.02	1.93	2.03	1,99
Kruskal-Wallis test									
Chi-squared		0.189	0.002	3.648	1.946	0.931	0.155	0.004	0.064
Asymptotic sig.		0.664	0.966	0.056	0.163	0.335	0.694	0.948	0.801

4.2 Green BMs: Value creation

Regarding value creation, the SMEs in the sample continue to include a very low number of environmental practices, on average about one (1.25 in 2016) out of the nine covered in the survey (Table 2). A significant difference was noted in the average value of the number of environmental initiatives among enterprises of different sizes, with medium enterprises using a larger number of practices (1.61), followed by small enterprises (1.21) and micro enterprises, which on average do not reach one (0.75) (Table 5).

Table 5. Value creation: differences by size

	Size	Value creation
Average values	Micro	0.75
	Small	1.21
	Medium	1.61
Kruskal-Wallis test	Chi-squared	12.392
	Asymptotic sig.	0.002

Regarding evolution over time, a slight, statistically significant increase was noted globally in the average number of environmental practices performed by SMEs from 2014 to 2016 (Table 6). However, when we performed this analysis distinguishing by size, we did not find significant differences, except that in the group of small enterprises, the difference is marginally supported with a $p < 0.10$ (Table 6).

Table 6. Value creation: evolution over time, globally and by size

		All SMEs	Micro	Small	Medium
Average values	2014	1.10	0.69	1.04	1,63
	2016	1.25	0.75	1.21	1,61
Kruskal-Wallis test					
Chi-squared		4.322	1.517	3.774	0.063
Asymptotic sig.		0.038	0.218	0.052	0.802

In spite of the slight improvement shown in the evolution over time analysis, the number of environmental practices performed by the SMEs is very low. We therefore consider it relevant to find which practices are the most widely adopted and if there are any differences in the degree of adoption depending on the size of the SMEs. Table 7 shows the percentage of adoption of each of the 9 practices and that most are not widely adopted among SMEs. The most widely adopted is recycling, reuse and valorization of the firm's sub-products and waste, which is adopted by 47.6% of the SMEs, followed by environmental audits at 28.9%. Of the 7 remaining practices, 2 are adopted by less than 15%, 2 by about 7% and 3 not even by 5%.

Table 7. Percentage of adoption of environmental practices: differences by SME size

Environmental practices	All SMEs	Micro	Small	Medium	Significant difference in size
Environmental audits	28.9%	13.73%	26.39%	43.57%	Chi-squared = 21.887 Asymptotic sig. = 0.000
Eco-design	3%	1.96%	2.38%	5.71%	Chi-squared = 4.360 Asymptotic sig. = 0.113
Eco-labeling	3.9%	1.96%	3.57%	5.71%	Chi-squared = 1.890 Asymptotic sig. = 0.389
Life cycle analysis	6.9%	1.96%	5.75%	12.86%	Chi-squared = 10.677 Asymptotic sig. = 0.005
Best available techniques	12.4%	1.96%	11.51%	19.29%	Chi-squared = 11.600 Asymptotic sig. = 0.003
Recycling and reuse of sub-products and waste	47.6%	29.41%	47.82%	53.57%	Chi-squared = 8.762 Asymptotic sig. = 0.013
Recycling and/or waste to generate energy	14.1%	15.69%	14.09%	13.57%	Chi-squared = 0.138 Asymptotic sig. = 0.933
Cogeneration and trigeneration	1.4%	1.96%	1.39%	1.43%	Chi-squared = 0.107 Asymptotic sig. = 0.948
Inclusion of renewable energy	7.2%	5.88%	7.74%	5.71%	Chi-squared = 0.813 Asymptotic sig. = 0.666

Table 7 also shows if there are any differences in the percentage of adoption of these environmental practices depending on size. The results vary and depend on the technique analyzed. For example, we found that in 4 of the 6 practices related to the generation of green products and processes (recycling and reuse of sub-products, environmental audits, analysis of best available techniques and life cycle analysis), there are significant differences by size in the percentage of adoption in SMEs. The table shows that in some cases, the differences are fairly large. In the other two product generation practices (eco-design and eco-labeling), even though there are differences in the percentages of adoption, these are not statistically

significant. Regarding the three practices relating to power generation, none of them shows statistically significant differences in the percentage of adoption in terms of size.

4.3 Green BMs: Value capture

The third component of BMs, value capture measured by CO₂ productivity, has an average value of 62.87 (Table 2), and no significant differences were observed for this variable among firms of different sizes (Table 8).

Table 8. Value capture: differences by size

	Size	Value capture
Average values	Micro	48.52
	Small	54.67
	Medium	97.02
Kruskal-Wallis test	Chi-squared	0.870
	Asymptotic sig.	0.647

In evolution over time of value capture, we noted a statistically significant increase in carbon productivity between 2014 and 2016. In evolution over time by size, we also found a statistically significant increase between micro and small enterprises. The increase in medium-sized enterprises is not statistically significant.

Table 9. Value capture: evolution over time, globally and by size

		All SMEs	Micro	Small	Medium
Average values	2014	52.90	38.95	50.53	72,52
	2016	62.87	48.52	54.67	97,02
Kruskal-Wallis test					
Chi-squared		9.185	5.357	5.669	0.497
Asymptotic sig.		0.002	0.021	0.017	0.481

4.4 Green BMs: Relationships among components

We start by analyzing whether firms whose value proposition places greater importance on reducing environmental impact (whether legally required or voluntary) are also more committed to value creation and capture.

Table 10 shows that firms that place greater importance on legally required or voluntary reduction of their environmental impact also in general adopt more environmental initiatives, and the differences are significant (Table 7). The firms that place great importance on the legally required and voluntary value proposition include 2 environmental initiatives, while those that place little importance on it barely include one. If we analyze these differences according to business size, they are also significant in the groups of small and medium enterprises.

Regarding whether the importance of the environmental value proposition affects value capture, we did not obtain any statistically significant difference.

Table 10. Differences between value proposition and creation: influence of size

		Value creation			
		All SMEs	Micro	Small	Medium
Legal proposition	Little importance	0.856	1	0.80	1.09
	Medium importance	1.641	0.67	1.50	2.33
	High importance	1.97	1.75	1.93	2.28
Voluntary proposition	Chi-squared	44.157	2.646	36.451	8.638
	Asymptotic sig.	0.000	0.266	0.000	0.013
Voluntary proposition	Little importance	0.786	0.80	0.74	1.05
	Medium importance	1.699	1.25	1.55	2.22
	High importance	2.164	1.50	2.15	2.50
Voluntary proposition	Chi-squared	60.899	0.779	50.176	9.620
	Asymptotic sig.	0.000	0.677	0.000	0.008

Finally, we also studied whether the greater or lesser creation of environmental value measured by the number of initiatives adopted by firms had a significant effect on the capture of environmental value but found no significant differences.

5. Conclusions

Transformation toward a low-carbon economy requires participation by society as a whole, and SMEs, which constitute the bulk of the business fabric in all countries, have a special role to play. However, the few studies performed in the environment field have mainly focused on large corporations, and the analysis of SMEs has been limited to specific cases that are particularly environmentally proactive. But what happens in most SMEs? How are such enterprises dealing with climate change? The BM literature tells us that innovation in BMs is especially accessible for SMEs and that when it includes environmental aspects, it can help in the process of transformation toward low-carbon economies. But are SMEs really participating extensively in this process?

The purpose of our study is to analyze how SMEs include product and process decarbonization in their BMs and how their size affects this inclusion. We used a database with 1,161 observations on SMEs, 466 in 2014 and 695 in 2016.

The results show that, in general, SMEs are not widely incorporating decarbonization in their BMs and that there are almost no significant differences by size. More specifically, the value proposition places medium importance on both legally required and voluntary reduction of the firm's environmental impact, whatever the size of the SME and the year analyzed. The ambivalent role of size discussed in the theory explains why there are no significant differences in this respect.

Moreover, the fact that the value propositions of SMEs regarding legally required and voluntary reduction of environmental impact are very similar and remain unchanged over time (also among SMEs of different sizes) seems to indicate that more rigorous regulations might have an influence on managers' environmental awareness. This is a possible avenue for future research.

Regarding the creation of environmental value, SMEs are adopting very few practices to help reduce CO₂ emissions. In 2016, 43.3% did not adopt any practice and 37.7% only adopted one or two. In this respect, there are significant differences according to SME size and over time, although the average values are always very low. Thus, it seems that the difficulties stemming from the small size of SMEs, such as lack of knowledge, lack of human and financial resources or general dependence on a small number of clients, outweigh the advantages. We consider that the definition of environmental practices adapted to SMEs and the training of managers might help enhance the value propositions of SMEs' Green BMs.

Finally, and regarding value capture (CO₂ productivity), size is not very relevant, although there is a positive and significant evolution over time that is maintained in micro and small enterprises. We believe the economic recovery of the Spanish economy over recent years, which has led to improved sales, might be the reason for this improved ratio.

It is also of interest that in this component, there is no significant difference between the firms that adopt most environmental initiatives and those that place greater importance on legal compliance or voluntary reduction of their environmental impact. This shows that not only do they adopt few environmental practices, but that these are not effective for reducing carbon. An explanation for this result might lie in the fact that the practices that are most widely adopted by SMEs, that is, recycling and environmental audits, are not very effective for reducing carbon. It is therefore important for SMEs to adopt more effective practices for carbon reduction (or specific adaptations of such practices for SMEs), such as product life cycle, eco-design or alternative power generation.

This diagnosis of Green BMs shows that SMEs need the help of the administration if they are to play a key role in the process of transformation of societies toward a low-carbon economy. Legislative actions that impose tougher environmental protection measures might help lead to value propositions that place greater importance on reducing environmental impact. Training actions on available environmental techniques and the promotion of research on the adaptation of such techniques to SMEs, as well as the adoption of specific practices for SMEs, might help enhance environmental value creation and capture in their BMs.

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