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Arranz, C.F.A, Kwong, C. and Sena, V. (2023) The effect of consumption and production policies on circular economy business models: a machine learning approach. Journal of Industrial Ecology, 38 (8). pp. 1493-1502. ISSN 1088-1980

https://doi.org/10.1111/jiec.13397

DOI: 10.1111/jiec.13397

RESEARCH ARTICLE

JOURNAL OF INDUSTRIAL ECOLOGY WILEY

The effect of consumption and production policies on circular economy business models

A machine learning approach

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Editor Managing Review: Xin Tong

Abstract

The circular economy (CE) is attracting increasing interest, as it can bring environmental, social, and economic benefits. However, policymakers and scholars appear to concentrate more on the production side of CE, while consumption, and particularly policies that affect consumption have received less attention and their effect is ambiguous. This paper investigates the effect of CE consumption policies on circular economy business models (CEBMs) in firms, but also examines the interplay this type of policies have with CE production policies to have a broader picture of the circular economy policy framework and the relevance of each type of policy on firms. While previous studies assume rational and passive consumer behavior, this paper borrows from a natural resource-based view and stakeholder theory, arguing that consumers have a proactive attitude toward the consumption of environmentally friendly products. Moreover, we use institutional theory as an analytical framework for modeling the effects of a particular policy framework on the CEBM. Our analysis combines classical econometric methods with machine learning approaches, employing data from the EU. The results show that CE policies aimed at promoting consumption have a direct and positive effect on CEBMs. This paper also confirms that a wide portfolio of CE policies on production and consumption has a greater effect on the development of CEBMs, due to the complementarity of CE consumption and production policies. Moreover, we show that in interaction with CE production policies, CE policies on consumption have an even greater effect on CEBMs in firms than would have been anticipated.

KEYWORDS
ANN, circular economy, consumption policy, industrial ecology, K-means cluster, machine learning

1 INTRODUCTION

Addressing the most pressing environmental concerns for society will necessarily involve radical adjustments to global production and consumption of energy, water, and natural resources. In this context, the circular economy (CE) is attracting increasing interest from government, business, society, and academia. This is reflected, for instance, in the European Circular Economy Action Plan (CEAP) and the Chinese Circular Economy Promotion Law (European Commission, 2015; Lieder & Rashid, 2016), or the initiatives by major companies, such as Google or Renault (Bocken et al., 2017), or in the significant growth in the number of scholarly publications and journals covering this issue (Geissdoerfer et al., 2017). This is because switching from a linear economy model to a circular one is widely recognized for bringing environmental, social, and financial benefits (Lewandowski, 2016). The use and reuse of resources, as well as the consequent decreased total resource inputs, energy, emissions, and waste leaks, could lessen the detrimental effects on the environment while maintaining prosperity and growth, at the same time striking a more beneficial balance between the economy, environment, and society (Geissdoerfer et al., 2018; Manninen et al., 2018). Implementing circular economy ideas frequently necessitates new visions, strategies, and policies, as well as a profound rethinking of product conceptions, service offerings, and channels for long-term solutions. (Bocken et al., 2016; Lewandowski, 2016).

The prominent role that institutions and governments have undertaken in the introduction of circular economy business models (CEBMs) reflects the growing importance of CE initiatives in firms (Bocken et al., 2016; Kristoffersen et al., 2021; Lewandowski, 2016). Authors have highlighted that governments and institutions develop a portfolio of policies, both aimed at the production system and consumption (Ariti et al., 2019; Kosow et al., 2022; Levänen et al., 2018; Milios, 2018). While policies that directly affect the productive drive have been shown to have a positive effect on organizations in the implementation of CE models (Merli et al., 2018; Phan & Baird, 2015; Wang et al., 2019), policies that affect consumption have received less attention and the results are ambiguous (Liobikienė & Dagiliūtė, 2016; Milios, 2018; Pollex & Lenschow, 2020). First, there is a considerable lack of studies on circular economy relating to consumption, only 19% of the literature describing the circular economy examined topics related to consumption (Kirchherr et al., 2017a). Second, it is not sufficiently clear whether consumers would engage in the circular economy or not, this is, due to cultural barriers or lack of consumer acceptance that create certain inertia that can hinder policies of institutions aimed at the diffusion of circular business models (Abbey et al., 2015; Hobson & Lynch, 2016; Kirchherr et al., 2017b, 2018). Third, unlike production policies that directly support companies in the development of CEBMs, consumption policies are oriented toward consumers,[1] and it is not clear, according to Mont and Heiskanen (2015) and Milios (2018), whether this type of policies implies a direct[2] or indirect[3] effect on companies, producing a weak situation or certain controversy in the effect of consumption policies on the implementation of sustainable policies. Ferasso et al. (2020) emphasize the importance of further investigating the interplay between institutions and circular business model transformations and the role of government policies in promoting "green" and sustainable societies.

It is in this context where this paper lies, by examining how CE consumption government policies affect business model activities related to circularity. This study not only examines CE consumption policies and their effect on CEBMs, but also investigates the interplay this type of policies have with CE production-oriented policies on the CEBMs in firms, in order to have a broader picture of the circular economy policy framework, and the relevance of each type of policy on firms. Departing from natural resource-based view (NRBV) and stakeholder theory, which highlight the role of external drivers for sustainability, indicating that firms' interaction with the natural environment leads to pressures exerted by customers, regulators, suppliers, and competitors, which act as drivers for more sustainable practices. Moreover, we use institutional theory, which indicates how policies push organizations to implement shared notions and processes (DiMaggio and Powell, 1983; Scott, 2005). Institutional theory has been frequently employed to explain firm implementation of organizational practices (Ariti et al., 2019; Berrone et al., 2013; Liang et al., 2007), particularly, in the environmental literature (Arranz et al., 2022; Gao et al., 2019; Wang et al., 2019). Furthermore, to study the effect of CE policies, this paper focuses on CE policies of the European Union (EU). Particularly, the CEAP adopted by the European Commission, which aims to help the EU in the transition toward a circular economy while decreasing the reliance on natural resources and creating long-term sustainable growth and employment. Despite the EU efforts for the progressive incorporation of important policies for the development of a circular economy, these policies have not been evaluated in detail. The case of the EU policies is interesting because it introduces initiatives throughout the whole product life cycle, both legislative and non-legislative measures, focusing on areas where EU intervention delivers real added value. These areas include how

[1] According to the European Commission (2015), consumption policies are measures and regulations that aim to guarantee customers' rights in relation to merchants, offer improved protection for vulnerable consumers, provide information, and regulate consumer behavior. Consumption policies have the potential to enhance market results for the economy as a whole. They make markets more equitable, and with better information offered to consumers, they can lead to greener and more social market results.

[2] The term "direct effect" refers to the non-mediated influence of one variable in the model or, more precisely, the sensitivity of the dependent variable (i.e., CEBMs) to changes in the independent variable of interest (i.e., consumption policies), while all other factors in the analysis remain constant (Asteriou & Hall, 2015). Hence, holding all other factors constant would cut off all causal paths, with the exception of the direct link between our independent variable of interest and the dependent variable, which is not intercepted by any intermediaries (Hayes, 2017). The direct effect of each variable is measured by the regression coefficient in our analysis.

[3] The term "indirect effect" (or mediation effect) refers to the transfer of an independent variable's effect on the dependent variable via one or more additional variables. These variables are known as mediator or intervening variables. In path analysis, mediation is defined as the indirect effect of an independent variable on a dependent variable that travels via one or more mediator variables. The indirect effect is computed by multiplying the paths that comprise the effect. The intensity of the indirect effect signals the amount of mediation that occurs via the relevant mediator variables (Hayes, 2017; MacKinnon et al., 1995).

products are designed, promotion of circular economy processes, stimulation of sustainable consumption, and waste prevention. This paper utilizes data from the EU Public Consultation on the Circular Economy database, which includes 870 companies.[4]

Therefore, the first question raised in this paper examines how the EU's CE consumption policies affect the implementation of CEBMs in firms. Then, since the effect of CE consumption policies cannot be analyzed in isolation, we raise a second question to study how the combination of CE consumption policies in interaction with CE production policies affects the development of CEBMs in firms. From a methodological perspective, we address these questions using a combination of classical econometric methods with machine learning approaches (i.e., artificial neural networks [ANN] and K-mean clusters), which allows a greater degree of understanding and explanatory power of how CE consumption policies affect the development CEBM in firms.

2 | LITERATURE REVIEW

2.1 | Circular economy

The circular economy is a cyclical system that seeks to minimize waste by converting end-of-life goods into resources for new products (Stahel, 2016). Closing material and product loops can lead to a process of continuous utilization of resources. This can be accomplished by long-lasting design, proactive maintenance, reusing, recycling, repairing, refurbishing, remanufacturing, and recovering instead of discarding, if not directly reducing the input of resources (Geissdoerfer et al., 2017; Reike et al., 2018). Following Kirchherr et al. (2017a), the circular economy "is an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. It operates at the micro-level (products, companies, consumers), meso-level (eco-industrial parks), and macro-level (city, region, nation, and beyond), with the aim of accomplishing sustainable development, thus simultaneously creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers." (p. 229). This definition emphasizes the role of businesses and consumers as enablers.

The literature on circular economy (CE) appears to concentrate more on the production side, from investigating circular business models (Chauhan et al., 2022; Rizos et al., 2016), to the development of circular value propositions strategies (Lewandowski, 2016), the examination of the advantages of these CE models (Geissdoerfer et al., 2017), food systems and supply chain (Else et al., 2022; Kusumowardani et al., 2022; Morais et al., 2021), and waste management (Ghisellini et al. 2016; McDowall et al., 2017). It seems that less attention has been paid to how the CE may influence consumption and consumers (Kirchherr et al., 2017a, 2018). The circular economy could translate into substantial changes in the daily lives of people and companies, as indicated by Hobson and Lynch (2016), nevertheless the current scientific literature seems to lack sufficient understanding of such changes and the policies that support the circular economy (Repo et al., 2018). Some of these changes require engaging in behaviors such as restoring and returning goods, by means of giving up the notion of ownership and newness (Schor, 2016; Tunn et al., 2019). Thus, these changes have raised some consumption problems, notably consumer adoption and acceptance, deterring the diffusion of circular business models (Saari et al., 2021). After examining companies in Europe, Kirchherr et al. (2017b) suggested that the apathy of consumers and the lack of awareness is the "main impediment regarding a transition towards CE" (p. 7). Previously, the same issue was raised by Rizos et al. (2016) from SMEs seeking to develop circular business models and strategies. They suggested that the "lack of support from demand networks" (p.10) discouraged eco-innovations such as circular business models from being introduced. This lack of understanding of consumers and consumption in the CE has deterred the development and implementation of CE policies aimed at consumption, narrowing the environmental scope of CE policies (Liobikienė & Dagiliūtė, 2016; Milios, 2018; Mostaghel & Chirumalla, 2021; Pollex & Lenschow, 2020).

2.2 | NRBV, stakeholder theory, institutional theory, and circular economy

Regarding the demand and consumers in the circular economy, Ghisellini et al. (2016) concluded that the current CE literature assumes consumers as passive and rational participants who, when making choices, would abide by labels as well as other signaling from the production side. However, contrary to the previous literature on CE, this paper, borrows from the NRBV and stakeholder theory, arguing that the consumer's proactive attitude toward the consumption of environmentally friendly goods has served as an incentive for the development of new products (Demirel and Kesidou, 2019). NRBV and stakeholder theory complement each other in explaining the decision of companies to eco-innovate CE models. NBRV and the stakeholder theory emphasize the external drivers of eco-innovation (Sarkis et al., 2010) for CE, indicating that by incorporating stakeholders, proactive firms manage to control their interactions with the natural world. The NBRV, in particular, stresses stakeholder involvement as a driver for the stewardship of products and the prevention of pollution (Barney et al., 2011; Hart & Dowell, 2011; Zhang & Walton, 2017). Furthermore,

[4] The whole database contains 1280 organizations and businesses. The final sample utilized in this paper includes 870 organizations after filtering and deleting incomplete replies and individuals.

stakeholder theory has noted that the stakeholder pressure exercised by customers, as well as other actors, act as drivers of eco-innovation of CE, both, in terms of product and process (Horbach, 2008; Lin et al., 2014; Rennings and Rammer, 2011).

Additionally, departing from NRBV and stakeholder theories and assumptions, this paper draws from institutional theory, which has been used widely in the literature to justify firms' implementation of organizational practices (Bag et al., 2021; Berrone et al., 2013; Gao et al., 2019; Liang et al., 2007; Wang et al., 2019). This theory postulates that organizations are not self-contained entities, but rather are shaped by norms, constraints, shared cognitions, structures, and societal expectations from relevant parties (DiMaggio and Powell, 1983; Scott, 2005). According to DiMaggio and Powell (1983) and Scott (2005), institutional pressures force organizations to acquire shared conceptions and procedures. More in detail, in this paper, we consider two dimensions of institutional pressures, the first one refers to CE consumption policies, considering both legislative policies, which regulate the market, and non-legislative measures or informative policies (Levänen et al., 2018; Milios, 2018; Pollex & Lenschow, 2020). Fundamentally, these policies are intended to promote the consumption of CE-compatible products, by influencing the consumer from both a compulsory and an informative point of view. The second dimension refers to CE production policies that directly support the development of CE models in companies, establishing a distinction between policies that support product development and those that affect the design of the process.

3 | HYPOTHESES

In terms, of how consumption policies aimed at promoting or facilitating CE affect a firm's CEBMs, this paper postulates there are two channels: through the demand of consumers, and by a consumer/provider duality of firms present in CE frameworks. First, as indicated in the literature review, CE literature assumes consumers as passive and rational participants (Ghisellini et al., 2016). However, this assumption is relaxed by employing NRBV and stakeholder theory, as other studies have noted (see, for instance, Albino et al., 2009; Iles, 2008). Therefore, we indicate that the environmental consciousness of consumers can act as a driver of environmental demand, or in this case, the demand for CE. Thus, when institutional forces, in the form of policies, are used to influence these consumers, these can, in turn, affect the development of activities related to circularity in firms, through this channel.

Second, regarding consumer/provider duality of firms. This channel stems from the nature of consumption and production of CE models. As indicated in the literature review, CE encourages the utilization of underused assets and the reutilization of existing goods, by engaging in collaborative consumption and the sharing economy (Belk, 2014). In this context of collaborative consumption, behaviors or activities in which consumers serve as both providers and "obtainers" of resources are recognized (Ertz et al., 2016). This is because unlike in traditional linear economy systems, durable products are leased, rented, or shared wherever possible, transforming businesses that traditionally purchased these goods, in consumers of other companies, with the incentive to ensure the return of these durable goods for subsequent reuse of the product or its materials and components at their end-of-life primary use period (MacArthur, 2013). Hence, in CE when referring to consumers we are not only looking at particulars but also firms. This duplicity of firms (as consumers and producers at the same time) in CE and the interaction of both roles in companies is important to investigate. As suggested by Tukker et al. (2017) firms play a crucial role in the contribution to sustainable consumption and production (SCP). They indicate that at a macro level, businesses are a powerful stakeholder in the national socio-economic systems of consumption and production, and that companies could be viewed as producers in business to consumer (B2C) or business to government (B2G) interactions, but also consumers in business to business (B2B) markets. This means, that in B2B engagement they also act as consumers and are affected by consumption-oriented policies. This is particularly relevant given the movement of outsourcing parts of the business in a globalized economy, leading to more frequent B2B interactions in today's business models (Dou & Sarkis, 2010). Given these channels, this paper investigates how CE consumption policies affect firms' CEBM. Hence, we propose:

Hypothesis 1: CE consumption policies positively affect CEBMs in firms.

In the previous hypothesis, we have postulated the positive effect that consumption policies as an institutional pressure have on the implementation of circular economy in companies. However, CE consumption policies do not work in isolation, there are also CE production-oriented policies that affect firms and their CEBMs. We expected them to interact and/or moderate each other when affecting the development of CEBM in firms, more than consumption policies alone. Wang et al. (2019) and Li and Yu (2011) have pointed out the direct effect that production policies have on the development of circular economy in firms. The development of CEBMs implies two main obstacles (Linder and Williander, 2017; Kirchherr et al., 2018). The first obstacle relates the difficulty of designing and creating products congruent with the CE model. The literature on product innovation highlights a collection of obstacles and constraints that businesses must overcome, including process uncertainty, market complexity, and managing organizational resources for innovation. In this sense, an institutional pressure in the form of financial support, to support technical uncertainty (production policy), plus consumption policies that help reduce market uncertainty, can help in the adoption of CE models in firms. Hence, the joint adoption of consumption and production policies is expected to have a greater positive effect on the implementation of CEBM in firms, than acting alone.

The second obstacle relates to the nature of the closed supply chains in CE models (Kirchherr et al., 2018; Lüdeke-Freund et al., 2019; Perey et al., 2018). From the perspective of the supply chain, CE models are present in a variety of processes and tasks that ranges from the design, manufacture, distribution, and product usage, to other processes involved in maintaining, reusing, recovering, and recycling materials and products. In other words, CE models incorporate producer organizations, consumers, and third parties (e.g., organizations devoted to the management of waste or suppliers of raw materials), intending to facilitate the development of CE-compatible products and processes. For the deployment of closed-loop systems, Lewandowski (2016) emphasized the significance of collaboration and cooperation across organizations. Nevertheless, forming partnerships is not without challenges (see, e.g., Arranz et al., 2016). Finding a suitable partner, coordinating processes, avoiding and addressing conflicts may deter organizations from cooperating to adopt CE models. In this context, institutional support can help mitigate the challenge that cooperation poses in the development of CEBM in firms (see, e.g., Ren et al., 2019 or Liao, 2018). Therefore, it is to be expected that a diversified portfolio of institutional CE policy pressures, ranging from production to consumption, will produce synergistic and complementary effects that have a greater effect on firms than only policies aimed at consumption. Hence, we propose:

Hypothesis 2: CE consumption policies in interrelation with CE production policies will positively affect CEBMs in firms more than if CE consumption policies acted alone.

4 | METHODOLOGY

4.1 | Sample

This paper employs data from the European Commission's *Public Consultation on the Circular Economy* database from 2015, since it includes 870 organizations from various economic sectors (European Commission, 2015). This database is utilized since it is the most current one generated at the European level in terms of CE. The procedure used is probability sampling, and it has a structure that is comparable to those produced by prior research. The data was gathered using an online survey, non-response bias was verified, as well as no significant differences between early and late respondents were found. The survey comprised the 27 EU Member States, Norway, Iceland, Switzerland, and Liechtenstein.

4.2 | Measure

4.2.1 | Dependent variable

As a dependent variable, we use the degree of development of the *CEBM*. A CEBM is defined as an company's or an ecosystem of companies' reasoning for creating, delivering, and capturing value while (i) slowing; (ii) closing; or (iii) narrowing resource flows (i.e., energy or materials) (Bocken et al., 2016; Massa et al., 2017; Osterwalder & Pigneur, 2010; Pieroni et al., 2021). For this, the questionnaire identifies various aspects or characteristics of the circular economy of companies that narrows or minimizes the flow of natural resources both in terms of product creation and in the process. The questionnaire presents the items displayed in Table 1. The relevance of each particular item is assessed using a Likert scale, ranging from "very important" (4) to "not important" (1). Following Costantini et al. (2017), the dependent variable *CEBM* is constructed as a cumulative index of the different CEBM elements. This method is used for the creation of the dependent variable since it allows measuring CEBM in all its breadth, while maintaining the typology of the measuring scale and with no loss of variance, as opposed to other methods. Moreover, it is a methodologically sound approach, as there is a high correlation between the variables (Cronbach's Alpha: 0.905), and their scales are consistent with each other.[5]

4.2.2 | Independent variables

In terms of the independent variables, these are represented by the different EU policies on CE aimed at consumption and production. These policies from the questionnaire arise from the CEAP adopted by the European Commission (European Commission, 2015).

The first group of variables refers to CE policies that affect consumption. We construct two variables for measuring consumption policies following Pollex and Lenschow (2020), which consider two dimensions of institutional pressures relating to consumption policies, that is, legislative policies, which regulate the market and consumers, and non-legislative measures, or informative policies. The first variable, *regulation*, captures

[5] Additionally, we have analyzed the robustness of this method comparing it to a variable created using factor analysis with principal components and varimax rotation (Kaiser-Meyer-Olkin [KMO]: 0.908; sig. 0.000; extracted variance: 50.286). After analyzing the correlation between the variable created as cumulative index and the one created with factor analysis, the result is 0.995. The advantage of the cumulative index is that it does not lose explained variance compared to that obtained by factor analysis.

TABLE 1 Description of the variables used in the analysis.

Dependent variable		Mean	Std. deviation
CEBM	i) Durability	3.25	1.147
	ii) Reparability: Availability of information on product repair (e.g., repair manuals)	2.94	1.339
	iii) Reparability: Product design facilitating maintenance and repair activities	3.08	1.354
	iv) Reparability: Availability of spare parts	3.01	1.339
	v)Upgradability and modularity	2.85	1.348
	vi) Reusability	3.09	1.176
	vii) Biodegradability and compostability	2.66	1.340
	viii) Resource use in the use phase (e.g., water efficiency)	3.31	0.933
	ix) Recyclability (e.g., dismantling, separation of components, information on chemical content)	3.50	0.923
	x) Increased content of reused parts or recycled materials	3.12	1.124
	xi) Increased content of renewable materials	3.02	1.122
	xii) Minimizing lifecycle environmental impacts	3.54	0.726
Independent variables (consumption)			
Regulation	i) Improve/clarify rules and practices affecting consumer protection (e.g., relating to legal and commercial guarantees)	3.15	1.103
	ii) Take action on product and material design	3.38	0.966
	iii) Encourage financial incentives to consumers at national level (e.g., by differentiated taxation levels depending on products' resource efficiency)	2.82	1.057
	iv) Take measures targeting public procurement (e.g., through criteria for Green Public Procurement)	2.63	1.320
	v) Encourage new modes of consumption such as shared ownership (e.g., car sharing), collaborative consumption, leasing, and the use of internet-based solutions	2.89	1.239
	vi) Promote the development of repair and maintenance services	2.94	1.278
Information	i) Provide more information relevant to the circular economy to consumers, for example, on the expected lifetime of products or availability of spare parts	2.96	1.239
	ii) Ensure the clarity, credibility, and relevance of consumer information related to the circular economy (e.g., via labels, advertising, marketing) and protect consumers from false and misleading information in this respect	2.59	1.412
	iii) Organize EU-wide awareness campaigns to promote the circular economy	2.81	1.377
	iv) Encourage waste prevention (e.g., minimizing food waste)	3.44	0.929

(Continues)

TABLE 1 (Continued)

Dependent variable		Mean	Std. deviation
Independent variables (production)			
Product	i) Establish binding rules on product design (e.g., minimum requirements on "durability" under Eco-design Directive 2009/125/EC)	3.12	1.005
	ii) Promote and/or enable the use of economic incentives for eco-innovation and sustainable product design	2.74	1.573
	iii) Review rules on legal and commercial guarantees	2.41	1.648
	iv) Encourage the consumption of green products (e.g., via rules on Extended Producer Responsibility schemes)	2.77	1.240
Process	i) Promote cooperation across value chains (e.g., through encouraging new managerial modes)	3.00	1.208
	ii) Support the development of innovative business models (e.g., leasing)	3.02	1.044
	iii) Improve the interface between chemicals and waste legislation	2.40	1.284
	iv) Promote collaboration between and among private and public sectors, including end-users	3.21	0.845
	v) Support the development of digital solutions	3.00	1.054
	vi) Identify and promote the exchange of best practice	3.18	1.009
	vii) Identify minimum standards for increasing resource-efficient processes (e.g., Best Available Techniques)	2.42	1.393
	viii) Provide access to finance for high-risk projects	2.55	1.293

legislative CE consumption policies that regulate the consumption of CE-compatible products to promote the circular economy. Following Milios (2018), we consider the items listed in Table 1 from the questionnaire to generate this variable (Cronbach's Alpha: 0.814).[6] The second variable, *information*, measures CE consumption policies of a non-legislative nature that aim to inform or encourage the consumption of products compatible with the circular economy. To generate this variable, we consider the policy items from the questionnaire (listed in Table 1), following Pollex and Lenschow (2020) and Levänen et al. (2018) (Cronbach's Alpha: 0.670).[7] In line with previous measures, a 4-point Likert scale was used ranging from "very important" (4) to "not important" (1). We construct these variables as a cumulative index in line with the dependent variable.

The next group of variables refers to CE policies that affect companies, in terms of production, for the development of CE models. As previously mentioned, these independent variables related to production-oriented EU policies are used to examine hypothesis 2 about the interaction of both, production and consumption policies, on the CEBMs. We construct these variables as a cumulative index, in line with the dependent variable and the previous independent variables. Arranz et al. (2022), Wang et al. (2019), and Ghisellini et al. (2016) highlight two distinct types of policy pressures used by governments and institutions to promote CE within firms that affect two key areas, that is, pressures that affect the product design and pressures that affect the production process. Hence, we generate two variables. The first variable measures the CE production policies that affect the development of CE-compatible products. Based on the questionnaire, we include the policy items listed in Table 1 to create the variable *product* (Cronbach's Alpha: 0.786).[8] The second variable measures CE production policies that affect the development of the CE production process. Similarly, we have extracted from the questionnaire the items listed in Table 1 to create the variable *process* (Cronbach's Alpha: 0.682).[9] In both cases, the relevance of each particular item is assessed on a 4-point Likert scale ranging from "very important" (4) to "not important" (1).

Moreover, we have analyzed the robustness of the construction of all four variables, examining the correlation between the constructed variable as a cumulative index and the variable constructed with factor analysis, and in all cases the correlation is greater than 0.9 (0.943; 0.921, 0.999; 0.993, respectively), corroborating the robustness of our constructs.

4.2.3 | Control variables

Moreover, from the questionnaire, we extract two control variables: *Environmentalmanagement and Sector*. The first control variable relates to the utilization of environmental management schemes at the firm level. The survey proposed the items in Table 1, which are used to generate a cumulative variable to measure if the company employs one or more environmental management schemes (listed in Table 1). The second control variable categorizes the sector in which the company operates (listed in Table 1). This variable takes the value 1 when the company is in the agricultural sector, 2 if it is in the industrial sector, and 3 if it is in the service sector.

4.2.4 | Econometric model

This paper employs an ordinal logistic regression (OLR), as well as two unsupervised machine learning methods, that is, a K-means cluster and ANN, to analyze the hypotheses.

For Hypothesis 1, we use an OLR to determine the direct effect of the different CE consumption policies on CEBMs, without considering the interaction with CE production policies variables. For the regression analysis, we have estimated two models, a basic model with the control variables and a complete model with the independent variables related to consumption.

$$\text{Model 1}: \quad CEBM = constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector) + e \tag{1}$$

$$\begin{aligned}\text{Model 2}: \quad CEBM &= constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector)\\ &\quad + \beta_3\,(regulation) + \beta_4\,(Information) + e\end{aligned} \tag{2}$$

For Hypothesis 2, we use a K-means cluster analysis combined with OLR, together with ANN, to examine how the interrelation of CE consumption and production policies has a greater effect on CEBMs than if consumption policies acted alone. First, we analyze the existence of different

[6] Furthermore, we have performed a confirmatory factor analysis with these items (KMO: 0.775; sig 0.000; explained variance 57.573%).
[7] Additionally, and in line with the previous variable, we have performed a confirmatory factor analysis with these items (KMO: 0.683; sig 0.000; explained variance 51.530%).
[8] Moreover, we have performed a confirmatory factor analysis with these items (with a single factor KMO: 0.749, sig: 0.000; and explained variance 61.289%).
[9] Additionally, we have performed a confirmatory factor analysis with these items (KMO: 0.764, sig: 0.000; explained variance 61.692%).

groups of companies, classifying companies according to the effect of production and consumption policies in interaction, and consumption policies alone. For this, we use the K-means cluster statistical model, which allows us to obtain different groups of companies. The K-means algorithm is a well-known centroid model clustering method (Huang, 1998). Each cluster is represented by a single mean vector, with the algorithms assigning an item to the nearest centroid. This means that K-means clustering uses Euclidean distance to identify reasonably homogenous groups of cases based on selected features (Solorio-Fernández et al., 2020). K-means allows handling large numbers of cases, which is appropriate for the analysis of this paper. As classification variables, we use CE consumption policies (*regulation* and *information*), and the interaction of CE consumption policies with CE production policies (including *product* and *process*). For the latter, we create a variable named *interaction*.

Second, once the companies have been classified into various groups or clusters, we address Hypothesis 2 by using an OLR model as the econometric model. As a dependent variable, we use the *CEBM* variable. In both cases, we introduce the independent variable representing the membership in the cluster (i.e., *cluster1 or cluster2)*, which is coded as a categorical variable. Therefore, the different regression coefficients should be interpreted as follows for the analysis of our results. The regression coefficient with value 0 corresponds to the reference category ($cluster_i$), while the remaining coefficients computed relate to the other categories ($cluster_j$), which represent the probability of developing CEBMs with respect to the first category. The models below are estimated to test Hypothesis 2, Models 3 to Model 6 relate to a pre-analysis of the hypothesis, whereas Model 7 corresponds to the regression analysis with clusters.

$$\text{Model 3}: \quad CEBM = constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector) + \beta_3\,(Product) + \beta_4\,(Process) + e \tag{3}$$

$$\text{Model 4}: \quad CEBM = constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector) + \beta_3\,(Regulation) + \beta_4\,(Information) + \beta_5\,(Product) + \beta_6\,(Process) + e \tag{4}$$

$$\text{Model 5}: CEBM = constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector) + \beta_3\,(Interaction) + e \tag{5}$$

$$\text{Model 6}: \quad CEBM = constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector) + \beta_3\,(Regulation) + \beta_4\,(Information) + \beta_5\,(Product) + \beta_6\,(Process) + \beta_7\,(Interaction) + e \tag{6}$$

$$\text{Model 7}: \quad CEBM = constant + \beta_1\,(Environmentalmanagement) + \beta_2\,(Sector) + \beta_3\,(Cluster1) + \beta_4\,(Cluster2) + e \tag{7}$$

Additionally, to understand in more detail how the various policies in interaction act, we perform an analysis with ANN,[10] to discriminate which policies have the most effect on the implementation of CEBMs. The ANN typology used in this paper is a radial basis function (RBF). RBFs are meant to approximate multivariable functions through the combination of different terms based on a single univariate function (i.e., the RBF). This is radialized to allow it to be utilized in several dimensions. Moreover, RBF is employed for the analysis since it is a feedforward,[11] supervised learning network[12] with an input layer, a hidden layer (known as the RBF layer), and an output layer. Table 3 and Figure 1 display the architecture of ANN-RBF used for the analysis. This neural network is based on the model below (Model 8) that is developed to examine the interaction of the different policies in more detail.

$$\text{Model 8}: \quad CEBM = f\,(Regulation; Information; Product; Process) \tag{8}$$

Moreover, following Ciurana et al. (2008) and Cavalieri et al. (2004), the sample is randomly divided into three subsamples (training, testing, and holdout), to avoid overfitting problems. The training sample consists of a set of data points from the dataset that is utilized to train the ANN model.

[10] This type of analysis is employed since ANNs show greater potential as predictive tools, compared to the performance of regression models (Gupta et al., 2019; Paruelo & Tomasel, 1997) where the interaction of various variables might involve non-linearity, not direct causality, and multi-interactions (e.g., Minbashian et al., 2010; Verlinden et al., 2008)

[11] This means that the data only flows in one direction, from the input neurons via the hidden layer of neurons to the output neurons (Reed & Marks II, 1999).

[12] That is, they map relationships implied by the data, so that the predicted results can be contrasted against the known values of the dependent variable (Mohrotra, 1997; Reed & Marks II, 1999).

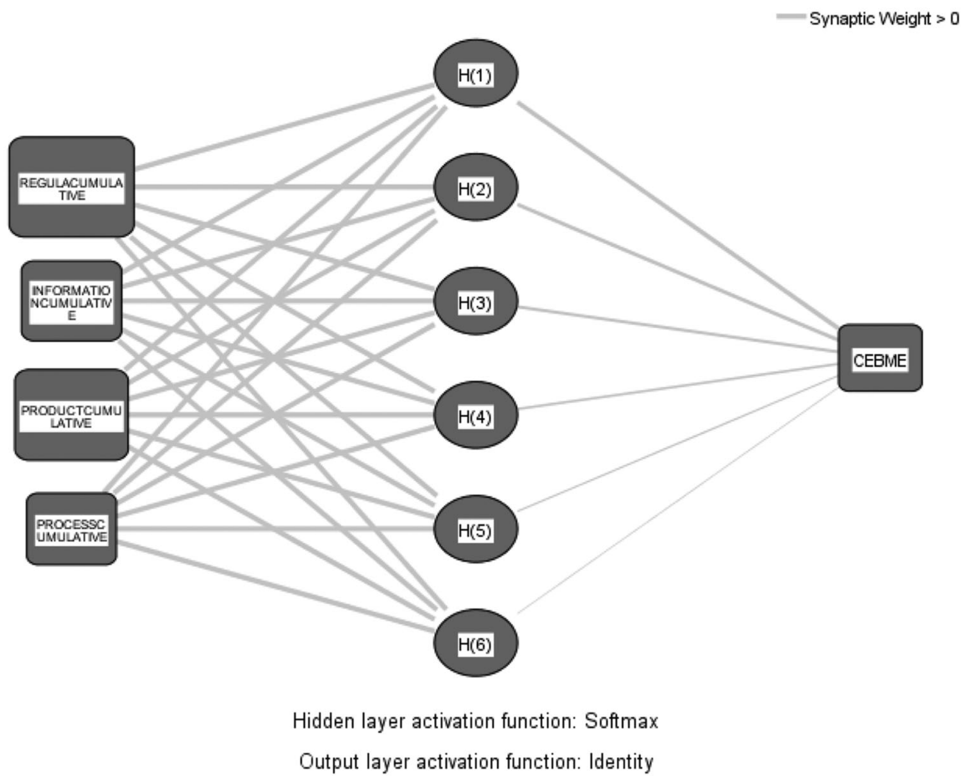


FIGURE 1 ANN-RBF architecture (underlying data for Figure 1 is available in Supporting Information S1).

The testing sample consists of a separate set of data points that are utilized to monitor the errors during the training stage to avoid overtraining. Generally, network training works best when the testing sample is smaller than the training sample. Finally, the holdout sample entails an additional separate set of data points utilized to evaluate the final ANN model. The error obtained for the holdout sample provides an "honest" assessment of the predictive capability of the model since the holdout cases are not utilized to develop the ANN model. Hence, the dataset was divided into a 7, 2, 1 configuration (this is because the relative proportions of the training, testing, and holdout samples relate roughly to 70%, 20%, and 10%). Moreover, as observed by Alloghani (2020), a training subset of around 60% is logical and aids in attaining the intended outcome without requiring more processing effort.

5 | ANALYSIS AND RESULTS

Regarding the empirical analysis, we have performed some test to examine the robustness of the questionnaire and the results. First, following Podsakoff et al. (2012) and Spector (2006), we tested the common method bias (CMB) and the common method variance (CMV). These analyses indicate the eight constructs that correspond to 63.072% of the variance. We can confirm that the CMB and CMV do not represent an issue in our model since the first factor is below the suggested threshold of 50% (23.676% of the variance). Second, the collinearity (Variance Inflation Factor, VIF) and autocorrelation (Durbin–Watson) were checked to assess the statistical robustness of the regression analysis. Table 2 presents the reliability and robustness of the results. We obtained values that are acceptable for both the VIF and Durbin–Watson tests (Hair, 2006). Finally, we conducted a reverse causality test, finding no evidence supporting any concerns relating to endogeneity.

Table 2 (Models 1 and 2) shows the results obtained from measuring the direct effect of the EU consumption policies for the circular economy on CEBM (Hypothesis 1). The results show that all CE consumption *regulation* policies ($\beta = 2.066$; $p < 0.001$) and *information* policies ($\beta = 1.231$; $p < 0.001$), have a positive and significant effect on the development of CEBM in the company.

Regarding Hypothesis 2, Table 2 (Models 3 to 7) display our results. First, we have carried out a pre-analysis, using regression analysis to examine the effect of the various CE policies, both production and consumption, on the development of CEBM, without considering their interaction (see Models 3 to 6). That is, Model 4 shows the positive effect of the CE policies, both production [*product* ($\beta = 0.159$; $p < 0.001$); *process* ($\beta = 0.060$; $p < 0.005$)] and consumption [*regulation* ($\beta = 0.245$; $p < 0.001$); *information* ($\beta = 0.203$; $p < 0.001$)], observing that these variables individually have a positive effect on the development of CEBM in companies. Moreover, Model 5 shows the interaction effect of CE production and consumption policies, obtaining a positive and significant effect [*interaction* ($\beta = 0.000$; $p < 0.001$)]. Finally, Model 6 shows the moderation analysis, which is

TABLE 2 Ordinal logistic regression models.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Regulation		2.066***		0.245***		1.586***	
Information		1.231***		0.203***		0.949***	
Product			1.521***	0.159***		0.662***	
Process			0.877***	0.060*		0.355*	
Interaction					0.000E+0***	−0.016	
Cluster 1							−2.964***
Cluster 2							0
Sector	0.254*	−0.006	0.260*	0.073	0.149	0.071	0.120
Environmental	−0.327	−0.128	−0.438	−0.254	−0.319	−0.286	−0.296
−2 Log likelihood	464.015	1353.457	1405.199	1267.046	1313.397	1259.567	
Chi-square	7.751	262.753	220.011	273.016	212.567	280.494	
Sig.	0.021	0.000	0.000	0.000	0.000	0.000	
Cox and Snell	0.031	0.681	0.613	0.714	0.623	0.724	
Nagelkerke	0.031	0.682	0.613	0.715	0.623	0.724	
McFadden	0.004	0.162	0.135	0.177	0.138	0.182	

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

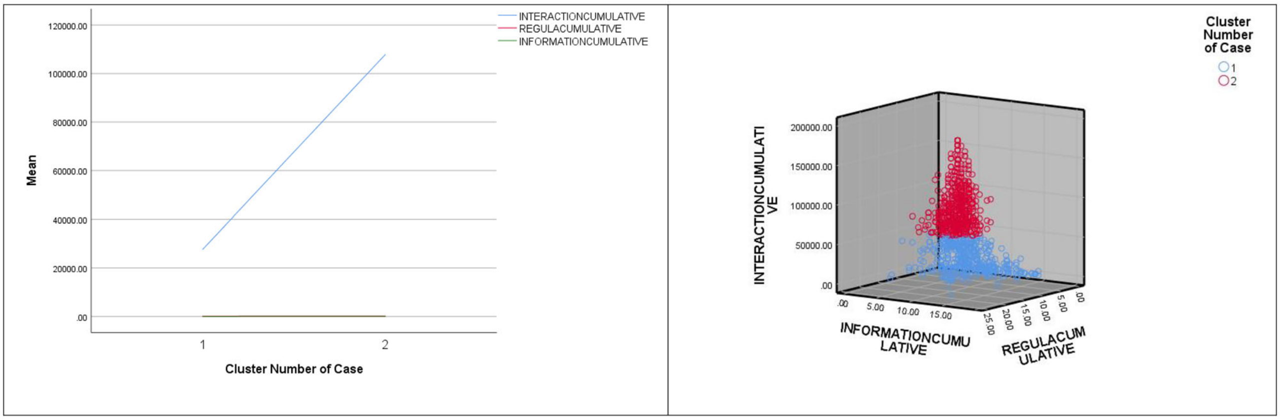


FIGURE 2 The effect of CE policies according to the cluster (underlying data for Figure 2 is available in Supporting Information S1).

inconclusive for our Hypothesis 2. Following Hair (2006), Minbashian et al. (2010), and Asteriou and Hall (2015), this has been explained as the difficulties of using regression models in moderation analysis, either due to the existence of collinearities, due to imbalances in the sample (this is especially critical in the use of OLR), or due to a low value of explained variance. To solve this difficulty, we have carried out a second analysis combining cluster analysis with regression analysis and ANN (Model 7).

To corroborate Hypothesis 2, we have first explored the behavioral patterns of companies in terms of the CE portfolio of impulse policies that affect them. The results of the K-mean cluster show two groups of companies, the first group consisting of 490 companies (Cluster 1), and the second group of 543 companies (Cluster 2). Concerning the differences in terms of the portfolio of institutional CE policy pressures between the two clusters, these are reflected in Figure 2. While we observe that the behavior of the two groups of companies in terms of CE consumption policies is relatively similar, we note that cluster 2 is characterized by being subject to a greater institutional pressure from both consumption and production CE policies in interaction. Figure 2 also shows the distribution and density of the distribution of the companies according to the cluster.

Table 2 (Model 7) shows the result of the regression analysis, using cluster membership as categorical variables. We observe that the results confirm our hypothesis (Hypothesis 2) since cluster 1 has a significant but negative coefficient ($\beta = -2.964$; $p < 0.001$), thereby confirming that the companies that belong to cluster 2, which are the companies affected by the interaction of both consumption and production CE policies, the probability of developing CEBMs is higher than in Cluster 1. Therefore, we can conclude that Hypothesis 2 is corroborated, confirming that a wide

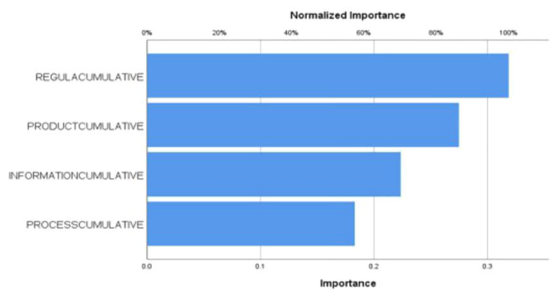
TABLE 3 ANN-RBF architecture.

Simulation	ANN architecture	Activation functions	Sum of squares error	Correlation: Output/predicted output
Regulation & Information & Product & Process	4-6-1	● SoftMax ● Identity	● Training: 0.314 ● Testing: 0.294 ● Holdout: 0.236	0.840***

*Error (cross-entropy).
**Correlation is significant at the 0.01 level (two tailed).

TABLE 4 ANN-RBF simulation for each of the independent variables.

	Simulation	
Variable	Importance	Normalized importance (%)
Regulation	0.319	100.0
Information	0.223	70.1
Product	0.275	86.2
Process	0.183	57.4



portfolio of CE policies on production (both in terms of product and processes) and consumption (both regulative and informative measures) have a greater effect on the development of CEBM in firms.

Furthermore, as previously mentioned, we have also performed an ANN-RBF analysis to distinguish which CE policies (i.e., consumption or production) when interaction has the most effect on the implementation of CEBMs in firms. As indicated by Cavalieri et al. (2004) and Ciurana et al. (2008), we have carried out two types of robustness tests for this analysis: the robustness of the ANN architecture and the robustness of the simulation. The robustness of the model is high taking into consideration both the error (0.314, in the training stage, and 0.294 in the testing stage) and the correlation of the ANN's predicted output with the actual output variable (0.840). This is shown in Table 3 which displays the ANN-RBF architecture for interaction analysis.

Focusing on the results of the simulation of the impact of CE policies for the development of CEBMs, Table 4 shows the normalized importance of the effect of each policy in the CE models developed by the firm. First, we observe that all policies have a positive and significant impact on the development of CEBMs. It is observed that *regulation* (0.319; 100% normalized value), *product* (0.275; 86.2% normalized value), *information* (0.223; 70.1% normalized value), and *process* (0.183; 57.4% normalized value) have a positive effect.

6 | DISCUSSION AND CONCLUSION

First of all, our results support Hypothesis 1, which highlights the positive impact of consumption policies, both regulatory and informative. These results corroborate the conclusions of Albino et al. (2009) and Iles (2008) and provide further empirical evidence to support the finding that consumers' environmental awareness can act as a driver of environmental demand, or in this case, the demand for CE. These results are also relevant as they refute the deeply rooted assumption in the circular economy literature that consumers are passive and rational participants who, when making decisions, would abide by labels and other signals on the production side (Ghisellini et al., 2016). Moreover, our results clarify the role of CE policies to promote green consumption, pointing out that both regulatory and information pressures, in the form of policies, are used to influence these consumers, which can, in turn, influence the development of activities related to circularity in companies, through this channel. These results are relevant because, on the one hand, highlight the importance of considering two dimensions of institutional pressures relating to consumption policies, as established by Pollex and Lenschow (2020), which can prove to be a useful classification for future research. On the other hand, they provide additional support to the perspectives, which in line with NRBV and stakeholder theory, indicate that institutional pressures exerted on consumption have a positive impact on customers, which in turn translates into, acting as drivers of green products (Horbach, 2008; Lin et al., 2014; Rennings and Rammer, 2011). Furthermore, not only does the pressure of institutional policies indirectly affect companies, but our results clarify how institutional momentum can directly affect companies, as consumers. This is an important finding as it emphasizes the role of CE consumption policies on the implementation of CEBMs, which have been largely relegated in favor of CE policies aimed at production (Friant et al., 2021; Kusumowardani et al., 2022; Milios, 2018). In fact, the limited CE legislation regarding consumption has been lax and led to ambiguous policies, for example, the EU "Right to repair" legislation has been criticized for the imprecise meaning of the provision of maintenance and reparability necessities in terms of "fair and reasonable conditions," which leads to both business and consumer uncertainty regarding CEBMs (MacAneney, 2018; Svensson et al., 2021). Therefore, policies such as the "Right to repair" legislation in the EU (Hernandez et al., 2020) or the French "reparability index" on electronics (Maitre-Ekern & Dalhammar, 2016) should receive more attention from institutions, as they affect the development of CEBMs.

Second, our results show the importance of developing policies that affect both the company and the consumer, but also act as a driver of CEBMs in companies. Our results show the complementarity of CE consumption and production policies aimed at the implementation of CE models in firms, corroborating Hypothesis 2. Thus, unlike previous studies that exclusively examine the effect of CE production policies on CEBMs in firms (see, e.g., Phan & Baird, 2015; Wang et al., 2019), our results provide robust empirical evidence that jointly developing CE consumption and production policies reinforce the implementation of CEBMs in companies. This finding is important because it indicates that despite the efforts of governments and institutions, such as the EU, for the progressive incorporation of crucial CE production policies for the development of a circular economy in many sectors, on their own, these measures are insufficient to result in a paradigm shift to achieve a transition for a circular economy, as consumption policies are also needed. These results are particularly relevant for the sustainable policy literature, as it sheds light on the disparity of results found when measuring the achievement of sustainable policy implementation (see, e.g., Liobikienė & Dagiliūtė, 2016). That is, because this body of literature fails to recognize the reinforcement effect that stems from the implementation of a comprehensive policy portfolio of CE consumption and production policies, as highlighted by our findings. Therefore, from an environmental policy perspective, our results emphasize the importance of a broad portfolio of CE policies that include both consumption and production-oriented policies, seeking to achieve the synergies and complementarities of them to drive the development of CEBMs in firms.

From a theoretical point of view, our research contributes to the literature on CE, and more specifically, the extant literature on consumption in the CE, improving the understanding of how CE consumption policies work in a CE policy framework, how they interact with CE production-oriented policies, and ultimately how they affect CEBMs in firms. While previous studies assume rational and passive consumer behavior, this paper borrows from NRBV and stakeholder theory, arguing that consumers have a proactive attitude toward the consumption of environmentally friendly products (Demirel and Kesidou, 2019). Moreover, we employ institutional theory as an analytical framework, for modeling the effects of a particular policy framework on the business model of a company related to circularity. Based on these assumptions, we postulate two channels for CE consumption-oriented policies, to affect CEBM in firms. These are through the demand of consumers, and by a consumer/provider duality of firms present in CE frameworks. The results of our analysis indicate that CE policies aimed at promoting consumption have a direct and positive effect on CEBMs. Moreover, this paper, by means of an OLR and K-means cluster analysis, also confirms that a wide portfolio of CE policies on production (both in terms of product and processes) and consumption (both regulative and informative measures) have a greater effect on the development of CEBM in firms, due to the complementarity of CE consumption and production policies. Moreover, utilizing an RBF-ANN, this paper shows that in interaction with CE production policies, CE policies on consumption have an even greater effect on CEBM in firms than would have been anticipated. In fact, they are more important than CE production policies, particularly CE consumption policies of a regulative nature, this means that measures that regulate the consumption for a CE, for example, regulating repair and maintenance services, or improving/clarifying consumer protection regulation and procedures. These results also accentuate the importance of consumption and production policies for CE literature, which is limited and requires further research in the future.

From a methodological point of view, the research contributes to a better understanding of the effect of CE consumption policies on CEBM. Through the use of regression analysis, ANNs, and K-means cluster, this paper studies the direct effect of CE consumption policies, but most importantly, the interaction with CE production policies (in the form of complementarity, interaction, nonlinearity). The combination of classical econometric methods with approaches from machine learning has allowed us a greater degree of understanding and explanatory power of how CE policies, in particular consumption-oriented CE policies, affect the CEBM in firms.

Last, our research provides some important implications for environmental policy and policymakers. Unlike previous research, our paper highlights the importance of complementarity and synergistic effects between CE policies. Thus, policymakers must pursue the application of broad portfolios of measures, which include both consumption and production policies, for a reinforce pressure of the development of CEBMs in firms, seeking both the depth and breadth of these portfolios, considering the circular nature of the CE model, which assumes that the actors play the double role of consumer–producer. Hence, more attention to CE consumption policies (particularly regulative measures) by policymakers is needed, which have been relegated in favor of other policies and play a crucial role for an effective policy framework that fosters the development of CEBMs in firms.

As with any research, this study has some limitations, which could provide fruitful avenues for future research. It is worth noting that the dependent and independent variables are self-assessed by the organizations that completed the EU survey, therefore, this research measures the potential impact these CE policies have on organizations from the perspective of EU businesses. Although this does not diminish the validity of the results and their contribution to the literature, future research could try to evaluate the ex post effect of these policies on firms.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in EuroGeoSurveys at https://ec.europa.eu/environment/consultations/closing_the_loop_en.htm.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Arranz, C. F. A., Kwong, C., & Sena, V. (2023). The effect of consumption and production policies on circular economy business models: A machine learning approach. *Journal of Industrial Ecology*, 1–16. https://doi.org/10.1111/jiec.13397