Dynamic Capabilities and Institutional Complexity: Exploring the Impact of Innovation and Financial Support Policies on the Circular Economy

Carlos F. A. Arranz, Vania Sena, and Caleb Kwong

***Abstract*—The adoption of the circular economy (CE) requires new strategies and policies to help firms in their transition. Despite this need, research on how to articulate policies for the transition towards a CE is still in its early stages, and the findings are inconclusive and even discrepant, especially concerning the necessary financial support or policies to foster systemic circular innovation in firms. The aim of this research is to analyze the effect of institutional pressures in these two areas on the adoption of CE in firms. To do this, from a theoretical perspective, we combine institutional theory, particularly institutional complexity, with the dynamic capabilities approach. From a methodological point of view, along with classical econometric methods, artificial neural networks and regression trees are applied to analyze data from European firms. The results show, first, that policies to foster innovation and financial support help in the adoption of CE in firms, but its effect follows an inverted U shape. This indicates that the institutional pressures embodied in these policies reach a threshold and that beyond that point, an increase in institutional pressures deteriorates the development of CE in firms. Second, the results show that within the portfolio of institutional pressures considered, there is a positive effect of a greater diversity of policies on CE development in firms. Lastly, the results demonstrate that innovation policies, when combined with financial policies produce synergistic effects on the adoption of CE in firms, greater than those observed when financial support policies are employed in isolation.**

***Index Terms*—Artificial neural network (ANN) models, circular economy (CE), decision trees, financial support policies, innovation, machine-learning, policies.**

I. Introduction

IN RECENT years, the circular economy (CE) has acquired significant notoriety on the agendas of governments, firms, and societies. There is a broad consensus on the need to transform linear production and consumption systems toward cyclical systems that eliminate waste and convert, at the end of their useful life, materials and products into new resources for production [1], [2], [3]. These cyclical systems allow continuous use of resources, reducing negative environmental impact while generating efficiency and financial benefits for firms [4], [5]. The CE has been a topic of significant interest within the academic community due to its potential impact on the environment. Many papers have been published in recent years on various aspects of the CE (e.g., [6], [7], [8]). However, a relatively small proportion of the academic literature has focused on examining the transition to a CE from a policy perspective at the national and international level [9], [10], [11], [12]. This is an issue that requires further consideration because as previously argued by Huamao and Fengqi [13] policy intervention facilitates overcoming the blockages of industrial systems and promotes the adoption of CE by firms.

From a theoretical point of view, the study of the influence of institutional pressures on the adoption of CE has been approached from different viewpoints. Thus, with a broad vision, Scott [14] and DiMaggio and Powell [15] showed the positive effect of coercive measures on the adoption of firm practices, such as CE practices, although their results are not conclusive regarding normative and mimetic measures. Other studies have focused on analyzing the effect of direct actions of environmental policies on certain aspects of the supply chain of firms and their impact on the adoption of CE [16]. For their part, Marrucci et al. [6] from the point of view of dynamic resources and capabilities, analyzed the influence of policies on the adoption of CE practices in firms. Although these investigations have made it possible to delve into certain aspects of the effects of environmental policies on the implementation of CE practices in firms, the results have not been conclusive, among other reasons, due to the diversity of environments studied, the different approaches, or the databases used in the analysis. Hence, as suggested by Milios [17], it is crucial to not only examine the impact of CE policies, but also to investigate how they impact various variables in order to determine their significance and any potential synergistic effects. Additionally, Milios [17] notes that there is a paucity of research on the use of policy to facilitate financial support or enable systemic circular innovation. This gap in knowledge is also highlighted by Su et al. [18], who identified a dearth of advanced technologies and insufficient economic incentives as primary impediments to achieving CE objectives.

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In this context, this article employs dynamic capabilities and institutional theory as the theoretical framework to analyze the research question of how innovation promotion and financial support policies influence the adoption of CE by firms? From the point of view of dynamic capabilities, the adoption of CE initiatives by firms entails the reorientation of its pre-existing capabilities toward establishing a proactive innovation process to support the adoption of sustainable growth models [6], [19], [20], [21]. For its part, the institutional theory emphasizes the significance of aligning the activities and strategies of firms to both stakeholders and institutions, in this case, the existence of a set of CE policies favors the transition of firms toward sustainable models, allowing firms to align their objectives with those of other interested parties [22].

In this article, we analyze two categories of policies. On the one hand, those aimed at promoting innovation, which as established in existing literature, facilitates the transformation of firms from the traditional linear economic model into a closed cycle model of production and consumption [1], [23], [24], [25]. On the other hand, financial support policies, both national and international, have also been highlighted in the literature to facilitate financial resources [6] and the adoption of strategies for the transition to CE models [14].

Based on this, this study aims to provide novel insight into the adoption of innovation and financial support policies in the context of CE. Specifically, the research explores the following research questions. First, unlike previous studies that have focused on examining which institutional drivers have the greatest effect on the transition to CE, this article investigates, how does the varying levels of certain institutional pressures influence the adoption of CE in firms?

Second, since institutions have a portfolio of policies both to promote innovation and financial support to facilitate this transition, how does the diversity of institutional pressures in the form of policies influence the adoption of CE by firms?

Finally, and in contrast to prior research, this article allows the different institutional pressures to interact to study the last question, does the joint effect of both types of policies have a larger impact on the adoption of CE models in firms than if these policies acted alone?

To address these questions, we use a dataset elaborated in the context of the EU´s Circular Economy Strategy, which includes a sample consisting of 870 firms. The methodology of this article employs a combination of machine learning techniques (i.e., artificial neural network and tree regression) and classical econometric methods, which allows for strong pattern recognition and to model the multivariate nonlinear relationships of different institutional pressures on the CE models in firms more effectively [26], [27].

II. Literature Review

A. Dynamic Capabilities Theory

The dynamic capabilities of the firm gather the set of high-level activities that allow directing normal operations into high-performance projects [6], [28], [29], [30], [31]. This analytical framework aims to systematize the different skills of the firm and help managers to prioritize and promote those that allow them to obtain a competitive advantage and adapt to market changes [32]. Teece et al. [33, p. 516] define dynamic capabilities as "the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments." This definition comprises two realities. On the one hand, the dynamics of the activities that allow the firm to change and evolve

1) detecting the opportunities and threats of the environment (e.g., consumer demand, technological possibilities) [34];
2) establishing the speed with which the firm can adapt to the changes detected [35];
3) maintaining, combining and growing the firm's tangible and intangible assets [36].

On the other, the efficiency with which the firm can carry out these changes in terms of strategies and resources [37], [38]. Strategies are the means and procedures that help achieve objectives by exploiting internal strengths (e.g., outperforming competitors, deciding when to enter the market), while resources reinforce and ensure the correct and efficient development of strategies. with the available means (buildings, equipment, intangible assets, etc.). In short, dynamic capabilities are the combined result of resources, learning, and corporate histories of the organization [39], [40].

B. Institutional Pressures and the Organization

The institutional theory explains how organizations adapt their actions and strategies to the social factors of their environment to gain legitimacy [41], [42], [15]. In practice, organizational behaviors are influenced by the external and institutional environment, which leads to the homogeneity of organizational forms and practices [43]. Adopting leading practices allows organizations to acquire and maintain legitimacy, regardless of business results [14], [15]. These contributions are particularly applicable from the point of view of the environment and many empirical studies have been based on these theoretical foundations [37], [43], [44], [45], as green investments often cannot be financially justified.

Although the theoretical research based on institutional theory is wide and prolific and ranges from the study of institutional logics (see, for example, [46] or [47]) to institutional entrepreneurship [46], [47], [48], our focus is framed from the perspective of institutional complexity [49], [50].

Institutional complexity rises when organizations are faced with incompatible requirements from multiple institutional logics [51]. Thornton [52, p. 70] defines institutional logic as "the sets of ideas and principles that govern how to interpret organizational reality, what constitutes appropriate behavior, and how to succeed." On the other hand, Teo et al. [53] and Scott [14] define institutional logic as institutional pressures or policies. That is, institutional logic offers organizations a way of understanding social reality and provides a framework to operate with confidence within the conditions prescribed by those logics or pressures [50], [54]. However, these institutional

logics (institutional pressures) may or may not be mutually incompatible [55], [56], [57]. Institutional complexity is, therefore, the result of multiple institutional pressures that interact and compete for influence in all socioeconomic domains of the organization [58]. In this context, if institutional pressures conflict, regulations embedded in business practices generate conflicting expectations in the organizations that are exposed to them and constitute an obstacle for firms to adopt and create capacities that allow them to face the changes. changes in the environment [51].

Two key aspects of institutional complexity have been indirectly addressed in previous literature. On the one hand, the increase in the number of institutional pressures is an important determinant of the complexity faced by firms and organizations [49], [50]. On the other, the level of incompatibility among such institutional pressures increases the complexity faced by firms, by revealing the divergence between the specificity of the means defined by institutional pressures and the goals pursued [49], [50], [56].

In practice, firms and organizations that choose a sustainable path face the complexity of environmental policy and the policy framework created around it. Although previous research has revealed the existence of multiple institutional pressures, it is necessary to deepen the knowledge of how firms respond to this complexity in practice, the result of the multiplicity of institutional pressures and the level of incompatibility among them. This article addresses some of these issues in the context of the CE, focusing not only on the pattern of the links between the different institutional pressures but also on the complexity derived from their interactions.

C. Circular Economy and the Firm

In the literature, the notion of the CE has been the subject of research through numerous studies and reviews that include both the natural sciences, the social sciences and engineering, and that show the relevance that this subject is acquiring [18], [25], [59], [60], [61].

The CE is a closed-loop economic model that reduces the requirements of raw materials and energy to mitigate the environmental impact of production and consumption, and in which waste is considered a valuable resource [25].

In contrast to the traditional linear economic model (take-use-throw away), the CE aims to repeat the use of resources and raw materials through multiple phases (maintenance, remanufacturing, reuse, and recycling of products), thus allowing their use more efficiently, the reduction of inputs, as well as the reduction of leaks and waste [3], [5], [62], [63]. The circular economic model is a cyclical system that transforms goods that are at the end of their useful life into resources to produce new goods [64]. Such a cyclical system enables continuous use of resources through durable design, maintenance, repair, and recycling, and closes the material loop in industrial ecosystems [65].

As explained by Urbinati [66], CE models imply a transformation in the way in which resources are used. Traditionally, in open or linear production systems, resources are employed to obtain finished products that, once consumed, become waste. By contrast, in closed or circular production systems, resources are reused in both production and consumption cycles. These processes reduce the waste of resources and maximize their efficient use while reducing the negative environmental effects of emissions derived from the production process [1], [22], [67].

D. Dynamic Capabilities, Institutional Pressures, and the Circular Economy

Both the institutional theory and the theory of dynamic capabilities coincide in pointing out the positive impact of public innovation and environmental policies to encourage the adoption of CE practices by firms.

Different authors have pointed out the important role of institutional pressures for pollution prevention and sustainable development [30], [31], [41]. These institutional pressures in the form of environmental policies act as drivers for compliance with CE in firms and organizations [68], [69] and their effects on the environmental practices of firms have been studied in the previous literature. Thus, Kraus et al. [37], Liao [70], Albort-Morant et al. [71], and Chang and Chen [72] analyzed the adoption of green innovations in those firms influenced by different institutional pressures. In general, the results show that firms tend to adapt their organizational structures and behaviors to external environments and institutional pressures to obtain legitimacy [41], [42], [68], [69]. In this sense, Wang et al. [43] pointed out that firms that are unfit for the institutional and external environment may become isolated. Therefore, due to the pressures of the institutional environment, firms tend to adopt CE practices even considering the complexity and possible incompatibility of those pressures [69]. The adoption of CE models requires that the firm be able to reconfigure its competencies and capacities, both internal and external, to carry out the necessary innovations for its implementation [30].

Previous research in the environmental field has studied the pressures of the institutional environment from different points of view [68], [73]. A usual approach has been to analyze the variety of institutional pressures (ranging from regulatory and coercive to purely informational pressures) and their implications for the firm [15], [74], [75]. Other approaches have focused on the effect of regulatory and political forces on the adoption of CE practices by firms [31], [59]. For their part, Bossle et al. [76] have analyzed whether subsidies and regulations favor investment by firms in closed-loop systems of use and production. A final point of view examines whether institutional pressures, as promoters of the adoption of environmental practices, have favored the attainment of resources and capabilities by firms [41], [70], [77].

In our article, we intend to combine the study of two little-studied dimensions: innovation promotion policies and financial support policies and their effect on the adoption of CE practices by firms.

III. Hypotheses

A. Intensity of Innovation and Financial Support Institutional Pressures on CE Adoption By Firms

Previous research has analyzed the effects of public policies on the CE strategy of firms, focusing on the study of which factors influence the development of environmental innovations and on the adoption of CE by firms [37], [68], [78]. In general, the findings indicate that regulations and subsidies favor investment in eco-innovation by firms [22], [30], [38], [41]. In the case of Europe, research shows a positive effect on CE of measures that favor eco-innovative development, as well as measures that promote the implementation of circular economic models by firms [69], [79], [80]. Therefore, based on this previous research, it can be concluded that policies, in the form of financial or eco-innovative support, favor the adoption of CE in firms and have a positive impact on business decisions to implement them. On the other hand, some research has shown that rigorous environmental guidelines can limit managerial decision capacity [81], raise costs, and force firms to make unprofitable investments [82], and even slow down the momentum of firms for the adoption of environmental practices [83], [84]. Other empirical evidence indicates that rigorous environmental regulation can lead to the reallocation of R&D toward pollution management and not toward the adoption of CE practices [85], [86]. These conflicting research findings can be explained, due to the fact that the literature has not analyzed the nonlinearity between the different institutional pressures on the adoption of CE practices by firms. Furthermore, most research assumes that the relationship between these institutional pressures is monotone and positive in nature [87], [88], [89].

In the context of dynamic capabilities, it is important that at high levels of policy implementation, in this case, both innovation and financial support policies, that firms possess the necessary capabilities and skills [36]. However, this can have a dissuasive effect, due to the paradoxical and complex situation where the development of these capabilities diverts attention from the fundamental objectives of the organization, and managers may become overwhelmed by the competing objectives [90], [91]. Managers may have difficulty effectively allocating their attention and energy, leading to conflicts and misunderstandings that hinder the effective implementation of processes that encompass both orientations [58] [91]. Furthermore, the high institutional pressure of these policies can expose employees to a variety of specific and sometimes contradictory tasks, leading to misunderstandings and hindering the innovative development of CE in firms. This effect can result in there not being a linear effect in the relationship between innovation policies and financial support in the development of the CE. Hence, as the level of institutional pressure increases, so does the complexity and therefore having a negative effect on the development of CE models within firms. From this perspective, we hypothesize the following:

Hypothesis 1a: *The effect of policies to promote innovation on the adoption of CE in firms follows an inverse-U shape.*

Hypothesis 1b: *The effect of policies to provide financial support for the adoption of CE in firms follows an inverse-U shape.*

B. Diversity of Institutional Pressures and Its Effects on the Adoption of CE in Firms

Both environmental management and the adoption of CE models by organizations require the integration of resources and skills (tacit knowledge, information, and technical systems, among others), which constitute one example of the development and use of dynamic capabilities by firms [6], [20], [22], [71]. The literature has shown that proactive environmental strategies are linked to the development of practices focused on CE-compatible processes and products [1], [30], [78], [92]. Thus, for example, the circular model fosters the utilization of biodegradable materials in the manufacture of products, which allows them to be returned to nature once their use has ended, respecting the environment. However, if these environmentally friendly alternatives are not possible (e.g., electronic components, batteries, etc.), the circular model is committed to the manufacture of easy-to-separate components that could be integrated into new products (thus facilitating their reuse) or for those nonbiodegradable or nonreusable products, the EC proposes a recycling that respects the environment. Therefore, the implementation of technologies that allow the adoption of a circular model of production and consumption in the firm is a great challenge from the point of view of innovation. Given that these strategies are not free of costs, institutional pressures intended to promote innovation and provide financial assistance may imply a positive boost in the adoption of a circular economic model by firms.

Unlike the traditional linear model, the circular model affects not only the entire value chain (design-manufacturing-distribution-use), but also the product's recycling processes after its usable life is finished. In turn, the adoption of sustainable practices engages producer and user organizations, as well as suppliers of raw materials and waste management firms. The implementation of CE models by the firm, especially if it involves more radical innovations, may also entail specific investments in R&D, which is why, on occasions, it may also involve cooperating with diverse research centers and corporations [44], [79], [64].

These circumstances justify public intervention through a wide range of policies that facilitate the development of products and practices compatible with the CE [93]. However, given the breadth and diversity of these measures (they vary from the regulation of the processes for the adoption of CE practices to the information on sustainable environmental practices and green markets; and from measures that facilitate the establishment of cooperation agreements to those that facilitate access to resources for the adoption of green innovations) can shape a complex institutional scenario in which firms face very different prescriptions that may even become incompatible.

However, beyond the problems that may arise from their implementation, we argue that policies to promote innovation and financial support will have a positive impact on the likelihood

that firms will embrace CE models. Therefore, we hypothesize the following:

Hypothesis 2a: *A greater diversity of policies to promote innovation in firms has a positive effect on the adoption of CE.*

Hypothesis 2b: *A greater diversity of policies to provide financial support for firms has a positive effect on the adoption of CE.*

C. Synergistic and Complementary Effects of Institutional Pressures in the Adoption of CE Practices in Firms

The interaction between variables describes a situation in which doing more than one activity increases the profitability of doing more of another [94]. In the case of resources and capabilities, Kristoffersen et al. [20] and Hullova et al. [95] point out that the interplay between these variables results from the affinity between them or from the development of already known tasks and routines. Likewise, Chang and Chen [72] and Binder [55] stress that the shared routines, competencies, and skills, as well as the learning and scale economies achieved in the firm's innovation processes, generate synergistic and complementary effects. Generally, the literature emphasizes that synergies are important in dynamic processes, particularly when studying social and business systems, given that interactions favor performance and the achievement of their objectives [27].

In the case of the transition of firms in the adoption of sustainable environmental practices, a key element is organizational changes [96], [97], [98]. The adoption of CE practices relies on the dynamic capabilities of firms (which integrate, among others, R&D, strategic planning, and product development) and imply the restructuration of the resources available and the coordination and integration of procedures. It also requires that they have a minimum level of skills that allow the development of sustainable products considering time and budget constraints [36], [99], [100], [101].

For example, the CE orientation of the firm implies the adoption of relevant regulations and standards, which requires the development of learning processes and organizational routines that facilitate their implementation. These processes and routines allow greater efficiency that facilitates, for example, the efficient management of waste and the recognition of areas for improvement, which in turn, allow for an adequate response to the results of monitoring and auditing [30], [102]. Collaboration is also a core element of dynamic capabilities that favors innovative activities development and facilitates the adaptation of firm resources and skills in response to changes in the environment [36]. In turn, organizational processes facilitate decision-making under uncertainty for managers and allow the design of CE-compatible business models, taking advantage of opportunities in the external environment [36].

In this context, despite the complexity that institutional policies can generate, the promotion of innovation favors the acquisition of capacities for the development of CE strategies by firms and organizations. However, this process is not free of costs, particularly in the case of smaller firms, for which the lack of financial resources or size may imply higher innovation costs than in the case of large firms when they implement CE-related technologies. Therefore, we expect that institutional pressures through innovation policies and financial assistance have a positive influence on the adoption of CE practices by firms, but also that the joint application of both types of policies will produce synergistic and complementary effects that reinforce the environmental orientation of firms. Therefore, we hypothesize the following:

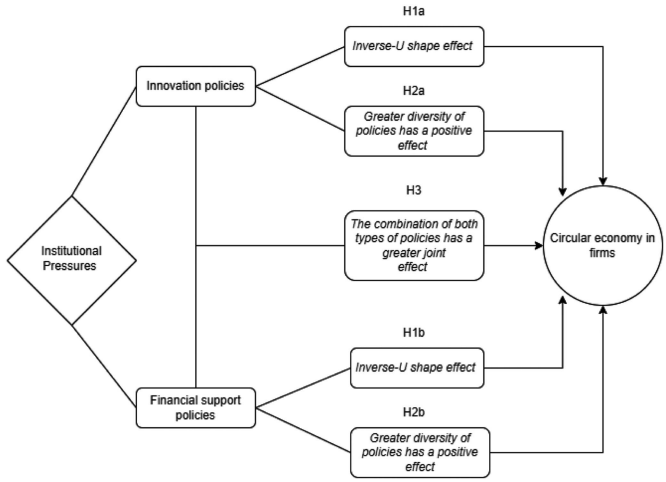


Fig. 1. Graphical model of the relationship between institutional pressures (i.e., innovation promotion and financial support policies) on circular economy in firms.

Hypothesis 3a. *A combination of innovation promotion and financial support policies has a greater joint effect on CE adoption in firms than policies to promote innovation alone.*

Hypothesis 3b. *A combination of innovation promotion and financial support policies has a greater joint effect on CE adoption in firms than financial support policies alone.*

Fig. 1 illustrates the graphical research model that shows the relationships between the different variables studied in this article.

IV. Methodology

A. Sample and the Context of the European Union

To analyze our hypotheses, we conducted an empirical study based on the EU Circular Economy Database [103]. The sample for this study consists of 870 firms from different economic sectors across the 27 EU Member States, including Norway, Iceland, Switzerland, and Liechtenstein. The data used was collected from a cross-sectional survey conducted by the European Commission in 2015, which is the most recent survey at the EU level regarding CE. The survey aims to understand the level of adoption of CE practices in European firms, the motivations behind this adoption, and how EU policies were impacting its implementation [103]. The sample included firms that have either adopted CE strategies within the last five years as a result of prior environmental improvements or have plans to implement such strategies within the next five years. The firms surveyed were from different economic sectors, with a balanced representation from both industrial and service sectors. Nearly half of the firms surveyed were large firms with 250 employees or more,

while 32.2% were small and medium-sized firms, and 23.2% were microfirms with fewer than 10 employees. The majority of firms surveyed were involved in environmental management, with the largest proportion of firms belonging to the recycling, other waste management, and repair services sectors. In terms of environmental management certifications, 52.2% of firms had implemented some type of certification, while 47.8% did not follow any environmental management scheme. The survey was conducted online using a "wave analysis" methodology over two weeks and was reviewed by a panel of CE experts [104]. Nonresponse bias was verified, and no significant differences were found between early and late respondents.

This study is contextualized within the European Union (EU) and its policy framework to facilitate the transition of firms toward the CE. This article utilizes the EU policy framework for several reasons. First, the EU is a global leader in implementing CE policy initiatives across the entire product life cycle, which provides an excellent case study to examine the impact of such policies [105]. Second, the EU's institutional drive toward sustainability and competitiveness within the European Union framework, demonstrated by the Circular Economy Action Plan (CEAP), outlines a comprehensive framework for implementing CE policies at an institutional level. This comprehensive framework allows us to study a larger breadth of policies for innovation and financial support and its effect on the CE in firms and obtain a more in-depth understanding. While China is the only other country that has implemented CE policies at a macro level, the measures implemented in the Chinese Circular Economy Promotion Law do not cover comprehensively all the aspects of the CE as the CEAP, which follows a more holistic approach [103], [106]. Moreover, the institutional pressure framework of the EU endeavors to encompass actions and initiatives throughout the entire product life cycle, "it targets how products are designed, promotes CE processes, encourages sustainable consumption, and aims to ensure that waste is prevented, and the resources used are kept in the EU economy for as long as possible" [105]. The EU's focus on product design, advancement of circular economy processes, encouragement of sustainable consumption, and waste prevention underscores the importance of this context in examining the impact of innovation and financial support policies that affect the circular economy at different stages of the product life cycle.

TABLE I
DESCRIPTION OF THE DEPENDENT VARIABLE

Variable	Items	Mean	St. Dev.
CE	Durability	3.25	1.147
	Reparability - Info for reparation	2.94	1.339
	Reparability - Product design	3.08	1.1354
	Reparability - Spare parts	3.01	1.339
	Upgradability and modularity	2.85	1.348
	Reusability	3.09	1.176
	Biodegradability & compostability	2.66	1.340
	Resource used in the use phase	3.31	.933
	Recyclability	3.50	.923
	Reused parts and materials in the content	3.12	1.124
	Renewable materials in the content	3.02	1.122
	Minimizing lifecycle environmental impacts	3.54	.726

TABLE II
DESCRIPTION OF INDEPENDENT VARIABLES

Variables	Items		Mean	St. Dev.
Innovation	Promotion of innovative business models for CE		2.84	1.214
	Specific measures to encourage the uptake of the CE among SMEs	2.95	1.152	
	Exchange and promotion of best practices		3.16	.872
	Promoting the development of skills/qualifications relevant to the CE	3.17	.902	
	Support for capacity-building in public administrations		2.66	1.252
	Support for market penetration of innovative projects through labelling	2.97	1.125	
	Better monitoring the implementation and impact of policies contributing towards the CE agenda	3.22	.935	
	Increasing the knowledge base by collecting and providing information and data	3.21	.946	
Financing	Financing innovative projects or technologies relevant to the circular economy	3.41	.776	
	Public incentives for private investors to finance projects conductive to the CE	3.13	1.001	
	Support for the development of CE projects	2.93	.996	
	Support for innovative systemic approaches & cross-sectional cooperation	3.17	1.067	

B. Measures

1) Dependent Variable: Our dependent variable is the degree of implementation of CE practices in firms, consistent with our hypotheses. We used a multi-item questionnaire (see Table I) that measures the actions taken by organizations to reduce natural resource consumption, promote the reuse, recycling, and repairability of products, and transform linear production processes into loop processes [25], [107]. To measure the firms' perceptions of these activities, we used a Likert scale ranging from 0 to 3 to indicate the importance of the activities undertaken by the firm. Consistent with previous studies [108], we used the degree of implementation of CE as a cumulative index of the actions taken by the firm. Creating this cumulative index required that the imputed variables be homogeneous in their measurement (Likert scale) and have a high level of correlation between variables with the same scale (Cronbach's alpha: 0.905).

2) Independent Variables: As stated in our research question, our study aims to analyze the effect of innovation and financing policies developed by the EU on the implementation of CE. The questions asked in the questionnaire followed the guidelines of the Circular Economy Action Plan adopted by the European Commission in 2015, which aims to stimulate the transition of the European economy toward a CE, seeking to improve competitiveness and environmental sustainability [103].

The first independent variable relates to policies that promote innovation. The questionnaire measures these policies using a multi-item question (seven items) and a Likert scale ranging from 0 to 3 to indicate the degree of importance of these policies in the development of CE (see Table II) (Cronbach's alpha: .750).

TABLE III
CONTROL VARIABLES

Variables	Items	Mean	St. Dv.
Enviromentalmanagement	EU eco-label	.143	.098
	Eco-Management and Audit Scheme (EMAS)	.025	.002
	Another environmental scheme	.010	.009
	No environmental management scheme	.552	.396
Sector	Industrial Sector	38.5%	
	Service Sector	61.5%	

The second independent variable addresses the effect of financial support policies on the development of CE (financing). In this case, the questionnaire contains four items (see Table II). Consistent with the previous variable, we used a Likert scale ranging from 0 to 3 to measure the degree of importance of this policy (Cronbach's alpha: .707).

3) Control Variables: To validate the robustness of our model, we included two control variables that have shown a positive and significant impact on the development of CE. The first variable is the use of environmental management systems and standards by firms [6]. In Table III, we present the various items used, using a binary variable to confirm whether these environmental systems are utilized or not.

The second question refers to the sector to which the firm belongs. We make a classic distinction in environmental studies [106] between the manufacturing and service sectors.

C. Econometric Models

Regarding the methodology used to corroborate the hypotheses, we will combine the classic statistical methods (ordinal logistic regression, OLR), with machine learning methods, more specifically artificial neural network (ANN) and tree regression analysis.

Using OLR, we analyzed hypotheses 1a and b. The dependent variable used is CE, while the independent variables are innovation and funding variables obtained through factor analysis. Additionally, to analyze the existence of nonlinear behaviors (concavity of relationships), we include the square of each independent variable to check for a U-inverted shape relationship. The analysis models are presented as follows:

Model 1:

$$\mathrm{CE} = \mathrm{constant} + \beta_1\,(\mathrm{Environmentalmanagement}) + \beta_2\,(\mathrm{Sector}) + e \tag{1}$$

Model 2:

$$\mathrm{CE} = \mathrm{constant} + \beta_1(\mathrm{Environmentalmanagement}) + \beta_2\,(\mathrm{Sector}) + \beta_3\,(\mathrm{innovation}) + \beta_4\left(\mathrm{innovation}^2\right) + e \tag{2}$$

Model 3:

$$\mathrm{CE} = \mathrm{constant} + \beta_1\,(\mathrm{Environmentalmanagement}) + \beta_2\,(\mathrm{Sector}) + \beta_3\,(\mathrm{financing}) + \beta_4\left(\mathrm{financing}^2\right) + e. \tag{3}$$

Consistent with the previous methodology, we will analyze hypotheses 2a and 2b using OLR as an econometric model. The dependent variable remains CE, and the independent variables are innovation policies and financial support. However, we measured the effect of policy diversity, constructing the independent variables as a cumulative index of innovation policies and financial support policies. This indicates that the greater the value, the greater the degree of policy diversity. Moreover, these variables are introduced into the regression model as categorical variables, allowing us to compare the degree of policy diversity in its effect on CE. The regression coefficients must be interpreted with respect to the reference category, indicating a positive or negative correlation. H0: ß $\leq$ 0 indicates that the regression coefficients are negative with respect to the reference category, indicating a lower probability of developing CE with that level of diversification. On the other hand, if the regression coefficient is positive with respect to the reference category (H1: ß$>$ 0), it indicates a higher probability of developing CE with that level of diversification. Furthermore, to determine if the relationship between CE and policy diversification follows a U-inverted shape, we include the square term of each variable in our model. The different models are shown as follows:

Model 4:

$$\mathrm{CE} = \mathrm{constant} + \beta_1\,(\mathrm{Environmentalmanagement}) + \beta_2\,(\mathrm{Sector}) + e \tag{4}$$

Model 5:

$$\mathrm{CE} = \mathrm{constant} + \beta_1\,(\mathrm{Environmentalmanagement}) + \beta_2\,(\mathrm{Sector}) + \beta_3\,(\mathrm{innovation}) + \beta_4\left(\mathrm{innovation}^2\right) + e \tag{5}$$

Model 6:

$$\mathrm{CE} = \mathrm{constant} + \beta_1\,(\mathrm{Environmentalmanagement}) + \beta_2\,(\mathrm{Sector}) + \beta_3\,(\mathrm{financing}) + \beta_4\left(\mathrm{financing}^2\right) + e. \tag{6}$$

Regarding hypotheses 3a and 3b, which analyze the interaction of innovation and financial policies, seeking to determine if there is a synergistic effect on the development of CE, we will use ANN combined with Tree Regression. Following Arranz et al. [27] and Wong et al. [26] we used a multilayer perceptron (MLP) as the type of ANN. In Fig. 2, we can see the structure of ANN-MLP. As we can see, the structure is composed of three types of layers. The first layer is determined by the number of input variables, while the last layer is the output variable layer. In between, we can find the hidden layers, which aim to analyze the relationship between the input variables, considering that this relationship is not necessarily linear. The econometric model for the ANN-MLP simulation includes financing, innovation, and financing*innovation as input variables.

Model 7:

$$\mathrm{CE} = f\,(\mathrm{financing};\ \mathrm{Innovation}). \tag{7}$$

ANN-MLP uses learning algorithms to design the architecture, using the trial-and-error procedure [109]. In this process, the number of hidden layers and neurons, as well as the specific weight of each neuron, are determined. Normally, one hidden

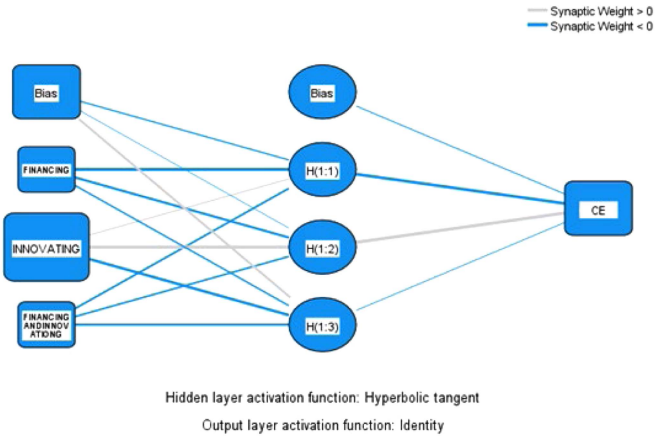


Fig. 2. ANN-MLP architecture.

TABLE IV
ANN-MLP ARCHITECTURE FOR INTERACTION ANALYSIS

Simulation	ANN architecture	Activation Functions	MSL error	Correlation: Output/Predicted Output
Financing Innovation Financing*Innovation	3-3-1	• Hyperbolic tangent • Identity	• Training: .755 • Testing: .713 • Holdout: .709	.699***

Note: *Error (Cross-entropy)
**Correlation is significant at the 0.01 level (2-tailed).

layer is usually sufficient to provide a robust solution. Additionally, in the architecture design process, the type of activation function of the hidden layer neurons and output is considered [110]. Usually, three types of activation functions can be used: logistic linear, tangential, and sigmoidal, which are conditioned by the input variable range [110]. Table IV and Fig. 2 contain the results of our ANN-MLP model design.

As a complement to the ANN-MLP analysis and with the aim to check the robustness of our analysis, we conducted a Tree Regression analysis. Thus, we tested different combinations of innovation and financial support variables in their effect on CE, analyzing the most likely ones.

Model 8:

$$\text{CE} = f\ (\text{financing};\ \text{Innovation})\,. \tag{8}$$

V. ANALYSIS AND RESULTS

Before discussing our hypotheses, we tested both the questionnaire and results to ensure the robustness of our empirical study. First, we analyzed the questionnaire responses to rule out any potential bias in the answers. To do this, we followed Podsakoff et al. [111] and examined the presence of common method bias. Our analysis ruled out the existence of this bias, as the first factor obtained from the factor analysis shows an explained variance of 24.772%, which is lower than 50% (the total explained variance by six factors is 63.072%). Additionally, we conducted an ANOVA test to check for significant differences in responses between firms that responded and those that did not, following Armstrong and Overton [104]. The results showed no significant differences among all the firms.

TABLE V
ORDINAL LOGISTIC REGRESSION MODELS (HYPOTHESIS 1A AND 1B)

Variables	Model 1	Model 2	Model 3
Financing	.552***		
Innovation		.1,204***	
Financing^2	–.008***		
Innovation^2		–.162***	
Financing*Innovation			.167***
Environmental	.096***	.143***	1.03***
Sector	.112***	.118***	1.25***
-2 Log-likelihood	4889.320	4725.902	4099.831
Chi-Square	438.119	421.256	394.830
Sig.	.000	.000	.000
Cox and Snell	.425	.399	.304
Nagelkerke	.425	.385	.302
McFadden	.109	.099	.077

TABLE VI
ORDINAL LOGISTIC REGRESSION MODELS (HYPOTHESIS 2A AND 2B)

Variables	Model 4	Model 5	Model 6
Financing	.134***		
Innovation		.256***	
Financing^2	–.003		
Innovation^2		–.004	
Financing*Innovation			.007***
Environmental	.133***	.105***	1.09***
Sector	.119***	.127***	1.16***
-2 Log Likelihood	4321.002	4109.341	3278.038
Chi-Square	325.729	310.372	281.392
Sig.	.000	.000	.000
Cox and Snell	.131	.187	.110
Nagelkerke	.129	.186	.105
McFadden	.056	.077	.023

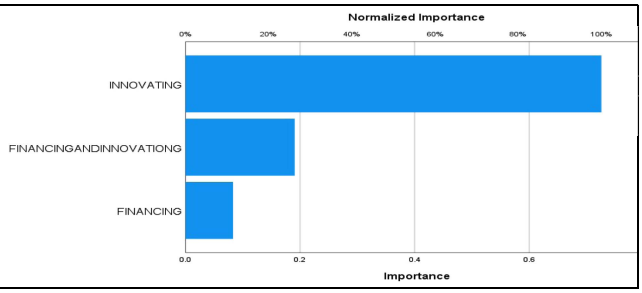
Lastly, we tested the robustness of our econometric models by analyzing collinearity (VIF) and autocorrelation (Durbin-Watson). As shown in Tables V and VI, the results demonstrate the robustness of our regression analyses. We also ruled out the existence of endogeneity by conducting a test of reverse causality.

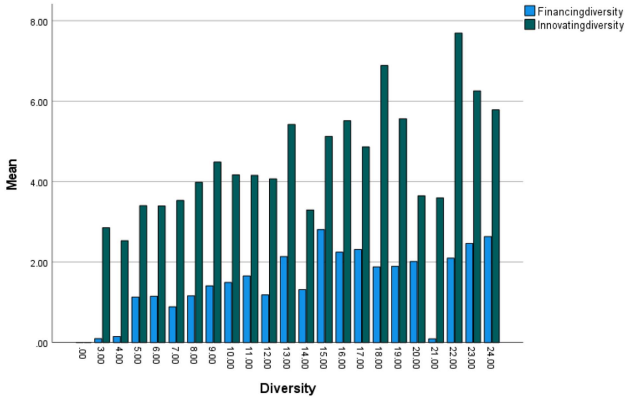
Table V shows the results of the regression analysis, confirming hypotheses 1a and 1b. Specifically, we found that both innovation policies [Innovation ($\beta = 1.204$; $p < 0.01$)] and financial support policies [Financing ($\beta = 0.552$; $p < 0.01$)] have a positive effect on CE. Furthermore, our results show the nonlinearity of the relationship between these policies and the development of CE, as indicated by the significant negative coefficients of the quadratic terms [i.e., Financing2 ($\beta = –0.008$, $p < 0.01$) and Innovation2 ($\beta = –0.162$, $p < 0.01$)]. In particular, we confirm that the relationship between these variables follows a U-shaped pattern, showing that for high levels of both innovation and financial support policies, there is a decrease in their effect on CE.

Regarding, Hypotheses 2a and 2b, our analysis of the effect of institutional policy diversity on CE development in firms is presented in Table VI and Fig. 3. The pretest in Table VI reveals that Financing ($\beta = 0.134$; $p < 0.01$) and Innovation ($\beta = 0.265$; $p < 0.01$) positively impact CE development, indicating that greater policy diversity increases the probability of CE adoption. Fig. 3 depicts the regression analysis results with categorical variables for the innovation and financial support policies, indicating that as policy diversity increases, the value of the

TABLE VII
ANN-MLP SIMULATION FOR EACH OF THE INDEPENDENT VARIABLES (HYPOTHESIS 3)

Variable (t-1)	Simulation	
	Importance	Normalized Importance (%)
Financial support	.083	11.4
*Financing*Innovation*	.191	26.3
Innovation	.726	100.0





(1) *Financing* Variable: OLR analysis. Pseudo R-Square (Cox and Snell: .122; McFadden: .020). -2 Log Likelihood: 1655.875; Chi-Square: 132.012; Sig. 0.000.
(2) *Innovation* Variable: OLR analysis. Pseudo R-Square (Cox and Snell:.356; McFadden: .067). -2 Log Likelihood: 1695.729; Chi-Square: 438.018; Sig. 0.000.

Fig. 3. Regression coefficients (Hypothesis 2a and 2b). (1) *Financing* Variable: OLR analysis. Pseudo R-Square (Cox and Snell: .122; McFadden: .020). -2 Log Likelihood: 1655.875; Chi-Square: 132.012; Sig. 0.000. (2) *Innovation* Variable: OLR analysis. Pseudo R-Square (Cox and Snell:.356; McFadden: .067). -2 Log Likelihood: 1695.729; Chi-Square: 438.018; Sig. 0.000.

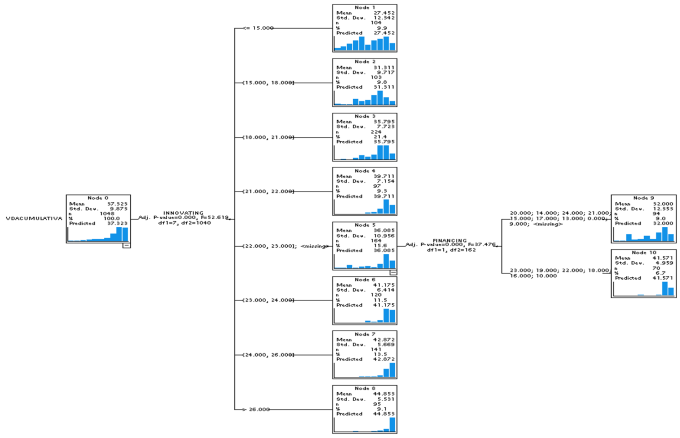


Fig. 4. Tree regression model (Hypothesis 3).

regression coefficients grows. Positive regression coefficients signify that the policies have a greater effect on CE development than the reference value, thus confirming both hypotheses.

Hypotheses 3a and 3b address the joint effect of policies promoting innovation and financial support on the adoption of CE in firms. Table VII presents the results. Table VII reveals that all variables have a positive and significant impact on CE adoption, with Innovation having the highest normalized importance (Innovation = 0.726; 100% normalized value; Financing∗Innovation = 0.191; 26.3% normalized value; Financing = 0.083; 11.4% normalized value) [112]. These findings confirm Hypothesis 3b, demonstrating the synergistic and complementary effect of both policies is greater than financial support policies alone. Nonetheless, Hypothesis 3a is not supported, as policies to promote innovation in isolation have a greater effect on the adoption of CE in firms than the joint effect of both policies.

The robustness of our findings was tested using a Tree regression analysis, which is presented in Fig. 4. The results demonstrate a positive relation between innovation promotion policies and CE adoption. Additionally, it supports Hypothesis 3b by showing that the combination of financial support and innovation policies has a larger impact on CE adoption compared to financial support policies alone. Nonetheless, the joint effect of the two variables does not have a greater impact on the probability of adopting CE than if innovation policies alone, not supporting Hypothesis 3a.

Moreover, Fig. 4 and Table VIII show the results of the analysis using the Chaid method, displaying the possible combinations of different values for institutional pressures. The decision tree is divided into two levels, the first corresponding to innovation policies, which has the greatest impact (F: 52.619; sig.: .000), and the second level showing financial support policies, which has a lower impact on the probability of CE adoption in firms (F: 37.476; sig.: .000). We identified the branches that are more likely to implement CE, and found that nodes 6, 7, and 8 have the highest probability of impact on the adoption of CE. Two observations were made from these nodes: the first is that the greatest impact on the probability of CE occurs when innovation policies act alone, and secondly, for maximum values of innovation policies (>26.00; innovation range from 0 to 28), the maximum value obtained for the probability of adopting CE is 44.853, when the maximum probability of CE adoption is 48 (variable range 0–48). This confirms the previously hypothesized U-inverted shape.

Additionally, the regression tree also considers the combined effect of innovation policies and financial support. This occurs at node 5, where we observe that the combination of innovation

TABLE VIII
TREE REGRESSION MODEL

Node	Mean	Std. Deviation	N	Percent	Predicted Mean	Parent Node	Primary Independent Variable					
							Variable	Sig.[a]	F	df1	df2	Split Values
0	37.3235	9.87328	1048	100.0%	37.3235							
1	27.4519	12.34211	104	9.9%	27.4519	0	INNOVATION	.000	52.619	7	1040	<= 15.000
2	31.3107	9.71660	103	9.8%	31.3107	0	INNOVATION	.000	52.619	7	1040	(15.000, 18.000]
3	35.7946	7.72294	224	21.4%	35.7946	0	INNOVATION	.000	52.619	7	1040	(18.000, 21.000]
4	39.7113	7.15448	97	9.3%	39.7113	0	INNOVATION	.000	52.619	7	1040	(21.000, 22.000]
5	36.0854	10.95580	164	15.6%	36.0854	0	INNOVATION	.000	52.619	7	1040	(22.000, 23.000], <missing>
6	41.1750	6.41383	120	11.5%	41.1750	0	INNOVATION	.000	52.619	7	1040	(23.000, 24.000]
7	42.8723	5.66928	141	13.5%	42.8723	0	INNOVATION	.000	52.619	7	1040	(24.000, 26.000]
8	44.8526	5.53128	95	9.1%	44.8526	0	INNOVATION	.000	52.619	7	1040	> 26.000
9	32.0000	12.35322	94	9.0%	32.0000	5	FINANCING	.000	37.476	1	162	20.000; 14.000; 24.000; 21.000; 15.000; 17.000; 13.000; .000; 9.000, <missing>
10	41.5714	4.95946	70	6.7%	41.5714	5	FINANCING	.000	37.476	1	162	23.000; 19.000; 22.000; 18.000; 16.000; 10.000

Note: Growing Method: CHAID:
Dependent Variable: CE:
a. Bonferroni adjusted.

and finance reaches maximum values of the probability of implementing CE of 32.000 (node 9) and 41.570 (node 10). This occurs for maximum values of the financing variable (range 0–24) and medium values of the innovation variable (range 0–48), indicating a substitution effect between the two variables. These results corroborate previous analyses, confirming hypotheses 1a and 1b.

VI. DISCUSSION

A. Theoretical Implications

The first contribution of this research is theoretical. First, this research advances the literature that studies the role of policies on CE implementation, and, in particular, the scant research into ways in which institutional pressures can influence financial support or facilitate systemic circular innovation.

More specifically, our results support Hypothesis 1a and 1b, which suggest that institutional policies, such as innovation promotion and financial support policies, have an inverted U-shaped effect on CE development [84]. The findings are partially aligned with previous research suggesting that both policies promoting environmental innovation, as well as financial support, can significantly influence firms' decision-making process toward CE practices' adoption [67], [73], [113], [114]. Furthermore, our study advances the knowledge of CE, by revealing that a strengthening of environmental policies can result in a decrease in the likelihood of CE's development. Thus, while the CE's development intensifies as institutional pressure increases, once a certain threshold point is reached, any further increase in pressures would deteriorate CE development in firms. Our finding aligns with other environmental research literature, including papers [83], [115], [116], which indicate that excessive institutional pressure to encourage innovation on green processes can be considered to interfere with corporate objectives by the firms. This further corroborates the research from dynamic capabilities [36], which indicates that at high levels of implementation policies, in this case, both innovation and financial support policies, firms need to possess the necessary capacities and skills, which can lead to paradoxical and complex situations where the development of these capabilities diverts attention from the fundamental objectives of the organization, and managers may become overwhelmed by the competing objectives [90], [91]. Furthermore, as these environmental objectives become normalized and are applied to all, it can cause CE-orientated firms to lose their competitive edge, and thereby interest in, these very objectives [83], [117].

Hence, our article advances previous research regarding the relationship between institutional pressures for CE adoption and the organization's strategies [73], [77], [118], by exploring how institutional pressures, both in the form of innovation promotion and financial support policies, affect firm's CE development. Our results confirm the positive effects of institutional pressures on

CE adoption and identify a negative effect when excessive institutional pressure is present, as demonstrated by the concavity of the curve between both variables.

Moreover, in Hypothesis 2a and 2b, the results indicate that a higher level of diversification in innovation and financial support policies has a positive effect on CE adoption within the firm. These results align with previous research demonstrating that proactive environmental strategies enable the transition towards closed-loop production and consumption business models [119], [120], [121]. This is because such strategies, including the adoption of CE models, imply the development of a large range of skills and capabilities in the firm, which often have a strong emphasis on product and sustainable processes development. Our study also supports earlier findings [73], [96] that institutional pressures can enable the creation of skills and collaboration capacities needed for the adoption of CE models by firms, despite potential complexity and incompatibility of these pressures on firms. These findings extend research on institutional complexity [49], [50], by showing that firms can confront and navigate through increasing institutional complexity and conflicting pressures by leveraging their competencies and capabilities to generate the innovative solutions needed for the implementation of CE.

Hence, our article extends the previous literature by highlighting the importance of a broad portfolio of institutional policy pressures on CE adoption [73], [93], [96]. This enriches the prior literature by explaining that while a greater and more diverse portfolio of institutional policy pressures creates institutional complexity experienced by firms, it also pushes firms to adopt CE models through re-configuring their capabilities and competencies.

Finally, our results partially support Hypothesis 3, showing a synergistic effect between institutional pressures in the form of financial support and innovation policies. However, this joint effect is not greater than policies promoting environmental innovation alone. Khan et al. [96], Annunziata et al. [100], and Strauss et al. [98] have indicated that firms face significant challenges in their efforts to develop CE, including the need to finance such initiatives, as well as developing skills and capabilities. The findings indicate that a combination of policies promoting innovation and financial support can enhance the improvement of skills by firms that enable the adoption of CE more so than those focusing only on financing their development. In contrast, the synergistic effect between innovation promotion and financial support policies is not found to be greater than innovation promotion policies alone. This can be explained by Daddi et al. [69] and Fischer and Pascucci [73], which noted that innovation policies can be more easily assimilated by firms through regulations and information. However, firms may face difficulties in accessing finance due to the complexity and administrative burden of the process, which can discourage them from seeking public financing [122], [123].

Thus, our findings support existing literature by emphasizing the importance of the complementarity and synergistic effects of policies for the promotion of innovation and financial support on capability development that facilitate CE adoption.

B. Methodological Implications

The second contribution of our research is methodological. Previous studies employed regression methods and focused solely on the analysis of the direct effect of institutional pressures on firms, which has led to inconclusive results (owing to the poor explanatory power of their models, low explained variance and/or low significance of the response variables), due to the nonlinearity, interaction, and synergistic effects that occur when considering complex institutional environments [50], [89], [116]. This research addresses these methodological problems by combining regression analysis with machine learning methods, which allows for strong pattern recognition and modelling the multivariate nonlinear relationships. Specifically, through the use of an ANN and a Tree Regression, the approach allows not only for the analysis of the interaction among variables but also for the consideration of non-linearities in the processes studied, improving explanatory power beyond regression methods. Our approach expands the methodology of previous research, such as Arranz et al. [27] and Wong et al. [26] which use similar modelling of ANNs to analyze the interaction among variables, by complementing it with the use of Tree Regression analysis to provide a more robust examination of the multivariate nonlinear relationship present in our research. Hence, this methodological approach contributes to the understanding of how institutional policies affect the adoption of CE and advances the discussion on the limitations of linear methods in analyzing complex relations among variables.

C. Managerial and Policy Implications

The study offers important implications for managers and practitioners. The findings of this research underscore the immense challenges that firm managers face when navigating institutional complexity. With a growing array of institutional pressures that come with complex and conflicting policy prescriptions, it is imperative for managers to prioritize the integration, cultivation and reconfiguration of their firm's competencies and capabilities, both internal and external, to facilitate the implementation of necessary innovation that would enhance CE adoption. This may involve prioritizing firm organizational objectives to allocate resources effectively, developing partnerships with other firms, investing in new technologies and processes, implementing clear communication channels with employees, and creating a culture of innovation and experimentation. As such, the findings have important implications for managers that to successfully navigate these pressures must continuingly innovate through CE adoption in order to remain relevant in the rapidly evolving business landscape.

The findings also offer important governmental implications for CE adoption in firms, by suggesting that, in order to facilitate CE adoption, policymakers need to consider an integrated and diverse policy framework, which supports both innovation and financial policies. In designing such policies, the emerging evidence from this study supports that policymakers should be aware of three crucial factors: intensity of institutional pressures, diversity in the portfolio of policies, and synergies between promotion policies for innovation and financial support. Thus,

policymakers have to be aware of the U-inversed shape nature of policies to foster circular innovation and financial support policies, which entails that the adoption of CE practices in firms only improves as the institutional pressures increase up to a certain threshold and then decrease subsequently. Hence, policymakers must be mindful of the intensity of institutional pressures while designing and implementing these policies to avoid an excessive level that generates adverse effects on CE adoption. The study findings also emphasize the importance of implementing both financial support and innovation promotion policies as they contribute positively to the adoption of CE practices in firms. By leveraging the synergistic effects of both innovation promotion and financial support policies, policymakers can enable firms to effectively adopt CE practices. Our results indicate that this combination has a greater impact on CE development than financial support policies alone. Nevertheless, in situations where policymakers are faced with a choice between implementing either innovation promotion policies or financial support policies, our results suggest that policies promoting innovation should be given priority since they have a greater impact on the adoption of CE practices.

D. Potential Avenues for Future Research

The present study, like any other research, is not immune to limitations. These constraints can offer valuable directions for future research. First, 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. While this does not undermine the validity of our findings or their contribution to the literature, future research could try to evaluate the ex-post effects of innovation and financial support policies on firms in the context of the CE.

Furthermore, the current study does not consider the impact of serendipity on the success of CE policies [124]. Serendipitous events can potentially have a significant impact on the success of policies designed to promote the development of CE models. Therefore, future research could explore how serendipity can affect the positive joint effect of policies to promote innovation and policies that promote financial support on the development of CE models. Finally, to build upon the findings of this study, future research could bridge the conversation with other management discussions that are outside the scope of this article. For example, future researchers could explore the analysis of contingent factors that influence the relationship between CE policies and organizational performance, or the role of contextual factors such as organizational culture, leadership, and innovation climate in moderating and shaping the impact of CE policies on organizational performance. This will help in developing a more nuanced understanding of the complexities involved in implementing CE policies in firms.

VII. Conclusion

This article analyzes the impact of institutional pressures, specifically innovation and financial policies on the adoption of CE in firms, utilizing data from 870 EU firms. We employed a combination of classical econometric approaches and machine learning methods to account for the nonlinear nature of the effect of institutional pressures on CE adoption in firms, as well as the interaction and synergies of these pressures. This approach has allowed us to understand the complexities of institutional pressures in the adoption of CE in firms, emphasizing three crucial factors: the intensity of institutional pressures, the diversity in the portfolio of policies, and the synergies between innovation and financial support policies.

In terms of the intensity of institutional pressures, our research identifies an inverted U-shaped effect of institutional pressures on CE adoption, which indicates that excessive innovation promotion and financial support policies to encourage CE can interfere with corporate objectives, making the development of necessary capabilities and skills challenging. This finding is consistent with previous research on dynamic capabilities, indicating that firms must possess the required competencies and skills to navigate such situations. Furthermore, our research indicates that a greater diversity of policies, both in terms of innovation and financial support, have a positive effect on CE adoption. This finding supports previous research that suggests proactive environmental strategies support the transition of linear economic models towards closed-loop models of production and consumption. Finally, our article demonstrates that there are synergistic effects among institutional pressures in the form of financial support and innovation policies. However, the joint effect is not greater than policies promoting environmental innovation alone. Access to finance can prove to be complex and administratively costly, which can disincentivize firms from seeking public financing, while increasing institutional complexity surrounding firms. At the same time, our findings indicate that an appropriate combination of innovation and financial support policies can enhance the acquisition of capabilities within firms that enable the implementation of CE more than policies focusing solely on financing. Thus, our article advances previous research not only by adding to the literature on the role of institutional pressures in CE adoption, but also methodologically through the use of an ANN and a Tree Regression analysis, which allow for the analysis of the interaction among variables, consideration of nonlinearities in the processes studied, improving explanatory power beyond regression methods.

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