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The Impact of R&D Investments on Eco-Innovation:A Cross-Cultural Perspective of Green Technology Management

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The Impact of R&D Investments on Eco-Innovation: A Cross-Cultural Perspective of Green Technology Management

Beatrice Orlando, Luca Vincenzo Ballestra, Veronica Scuotto, Marco Pironti, and Manlio Del Giudice

***Abstract*—This article originally seeks to explore the impact of R&D investments and societal culture on green technology management, by applying Hofstede's cross-cultural perspective. At large, we investigate if green innovation is positively associated to country cultural indulgence, as this factor indicates that basic needs are already satisfied and there is room for looking into hierarchically higher concerns. We also argue that governments' expenditures in green innovation tend to be more effective than those of firms, because governments are more willing to invest and risk in radical innovations than businesses. The analysis is conducted on a large-scale sample of data drawn from Eurostat, including information on R&D expenditures and on eco-innovation index from European firms and governments. The results confirm our model hypotheses: governments' investments largely predict eco-innovation, differently from firms' expenditures. Moreover, as supposed, country's cultural indulgence has a positive effect on the eco-innovation index as well.**

***Index Terms*—Eco-innovation, green innovation, green technology management, Hofstede's scale, indulgence, R&D investments, sustainable development.**

I. Introduction

THIS article aims to study the impact of R&D expenditures and societal culture on green innovation management. In particular, we consider how both governments' and firms' R&D expenditures impact the eco-innovation index. In addition, we search to understand whether there is an association between eco-innovation and cultural indulgence. In doing so, we adopt a motivational framework to detangle the concept of sustainable development.

As a matter of fact, whilst some countries seem ahead of the sustainable development mantra, others lag far beyond. As instance, according to The Environmental Performance Index (EPI), countries such as France and Denmark are among the top five, whereas Italy ranks only 16 in this list.

The EPI is a global ranking that rates the sustainability level of nations by air quality, water and sanitation, heavy metals, biodiversity and habitat, forests, fisheries, climate and energy, air pollution, water resources, and agriculture.

However, the European Union shares common laws on this theme, and all countries may have the same access to incentives.

Therefore, the first rationale that motivated this study is the search for factors that actually impact the sustainability of a country.

Intuitively, societal culture may play a relevant role in this sense.

Second, both firms and governments are investing in green innovation. However, there are no information on the effectiveness of those investments so far. Yet, governments may be more forward looking than firms, because they are less biased by factors such as uncertainty, risk aversion, or lack of capitals.

Thus, the general purpose of this article is to understand what actually impacts eco-innovation, at both micro and macro levels of analysis.

At large, sustainable development is long been intended as a sort of utopia, a heuristic concept, such as those of equality and freedom [65], used to identify an ideal process toward a more eco-conscious behavior of governments, business, and society. This construct is inherently based on the idea of a trade-off between current and future environmental needs [13], [53], [59], [67], because the current use of natural resources should be such that it neither undermines the ecosystem nor it compromises the living conditions of future generations [68].

The concept of sustainable development, used as a synonym of sustainability, emerged during the 80s of past century [68], as the result of the environmental concern combined with its economic and social consequences. In a nutshell, the conception of sustainability embraces two antithetical approaches: the utilitarian approach and the spiritual approach [68].

Accordingly, development is sustainable when it creates value in the long run [44]. However, the spectrum of ways through

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which sustainable value creation should be achieved is vast and resents of the inherent friction between the two alternative viewpoints. Precisely, the academic debate is centered around two disagreeing visions [68]: the eco-centric and technocentric approaches [60].

The first one puts the individual human responsibility at the core of the matter. Consistently, humans have to change their attitude toward the environment. Instead, for the second, pragmatic view, sustainable development can only be achieved through green technology efficiency. The World Conservation strategy [60] attempted to overcome the short-termism of the eco-centric approach, focused on limiting environmental damages in the short term, by considering institutional changes required for the conservation of the environment [39]. Years later, this resulted in the first report of the World Commission on environment and development [88], where it is explicitly recognized that environmental preservation requires, at first, the solution of the problem of poverty around the world.

Intuitively, according to motivation theories [32], [48], [50], [78], the preservation of the environment only matters when basic needs are already satisfied.

Also, the dichotomy between the two conflicting envisions of sustainable development that led to vagueness in the concept faced up with the problem of cosmetic or fake environmentalism [68], because of a lack of objective measures of the environmental impact. An attempt to operationalize the construct and to provide unobstructed measures of sustainable development was made, as instance, with the Kyoto protocol. The protocol defined specific actions for saving the environment and limiting the growth to sustainable levels.

Aforementioned actions are defined in conformity with the logic of technology efficiency and they presume eco-innovation. Thus, the concept of green technology management emerged rather recently. At large, it refers to those R&D investments aimed at generating sustainable technological innovations, as instance as renewable energy or clean power (e.g., bioreactors, electric vehicles, wave energy, etc.). At the firm level, the operationalization of the notion of sustainable development has set a new standard of environmental competitiveness, based on innovation offsets [62], whose definition is an innovation that "lower the net cost of meeting environmental regulations, but can even lead to absolute advantages over firms in foreign countries not subject to similar regulations." [62, p. 98].

Yet, the business-based view of sustainable development reflects, once again, the disagreement between the two aforementioned approaches. In sum, the firm perspective is pragmatic, oriented toward efficiency, and, sometimes, it might hide fake greenery behaviors.

Above considerations led us to define our first research question: is green innovation related to societal culture?

By paraphrasing Robinson [68], we searched to understand how it is possible to "square the root" and to provide a novel view of sustainable development, which is simultaneously eco-centric and technocentric. Robinson and Tinker [69] argued that governments must reflect the value of people. To this end, we combine the consideration of green technology management with those of cross-cultural factors [32], [74] in European countries. As a matter of fact, it was verified that the cross-cultural scale can only be applied to Western countries [1]. Cross-cultural scale refers to cultural distances between country culture, based on a set of specified parameters. It studies the impact of social culture on its members.

Drawing on motivation theories, we argue individuals are more environment-sensitive when the other basic needs are already satisfied. This is consistent with the logic of the report of the World Commission on environment and development. In the cross-cultural framework [35], the need for enjoyment is related to cultural indulgence and depends on having already satisfied basic needs. Thus, we investigate whether there is an association between cultural indulgence and the eco-innovation index. This index, released by Eurostat, expresses the green innovation efficiency of European member states. This way we reconcile the two disagreeing eco-centric and technocentric approaches.

Second, we argue that there exists a different tension between governments and businesses toward sustainability, which is reflected by a likewise different commitment toward eco-innovation. Prior literature fails to capture the aforementioned friction and the span of its effects on the effectiveness of green technology management policies. As a matter of fact, antecedent studies are mostly focused on the design of eco-innovation [9], [23], [81], [82], [89] and on its effects on firm's performance [46]. Also, often firms suffer from fake greenery attitudes. Then, our ulterior research questions are aimed at understanding whether there is a difference between governments and firms R&D expenditures in green innovation and how this impacts the eco-innovation index.

Hypotheses are tested on a large-scale sample of data drawn from Eurostat, the statistical office of the European Union.

Data refer to R&D innovation expenditures of both European firms and governments, grouped by country. Firms' sample includes either large or SME's enterprises.

Our finding confirms the hypotheses at level of high statistical significance. Indulgence and the eco-innovation index are associated, indeed. Also, governments are more environmental-conscious than firms. They spend more in green innovation and their impact is more effective than the one of firms.

Our original study reconciles the different factions on the concept of sustainable development. Green technology management is strictly entwined with cultural factors. Also, it requires radical, systemic innovations. In this sense, the role of governments is of the paramount relevance.

Rest of this article are organized as follows: first, we review the literature on this theme, we identify the gaps, and we state our hypotheses; second, we empirically test the hypotheses and we discuss our findings; finally, we explain the implications of the study, along with future research avenues and concludes this article.

II. Research Background and Hypotheses

A. Motivation Theories, Cross-Cultural Factors, and Sustainable Behaviors

The transition toward a sustainable future requires a widespread behavioral change [52]. A fast change in social

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vision and consequently behaviors, it is needed to avoid the "ecological holocaust" [63] due to exceeding "the earth carrying capacity" [52, p. 531]. In this vein, a relevant perspective supported by McKenzie-Mohr [52] suggested the idea that environmental changes are driven by those actions that induce society to actively desire sustainability. As a matter of fact, financial incentives along with knowledge dissemination programs and campaigns have proved themselves ineffective [52].

Accordingly, societal culture may be either a barrier or a factor fostering sustainability.

Consistently, a nourished stream of research studied motivational factors related to green behaviors. As instance, Griskevicius *et al*. [29] suggested that there are evolutionary reasons that motivate whether people adopt green behaviors or not, such as reasons that are inherited at social level and reflect the pro-social behavior and the group identity. The authors, then, argued that "people are particularly motivated to compete for status through proenvironmental behaviors that can signal self-sacrifice" [29, p. 121]. In addition, copying eco-behaviors determine an adaptive advantage when the society adds value to such green attitude show-off [56]. Also, environmental problems are inherently a social dilemma that determines the social intention [43], [90].

In his review work, Trudel [86] identified four categories of motivations for green behaviors: cognitive barriers, the self, social influence, and product characteristics.

Thus, apparently, the social culture has a huge influence on green behaviors [9].

Hofstede [36] originally proposed a cross-cultural scale.

According to Hofstede [33], culture can be described as a sort of collective programming of the mind that varies between groups. In his early study, he identifies four cultural dimensions: individualism-collectivism; uncertainty avoidance; power distance (strength of social hierarchy); and masculinity-femininity (task-orientation versus person-orientation). Later, two further dimensions were added: long-term orientation and indulgence [34].

Power distance measures the extent to which the less powerful members in a society accept that power is not equally distributed. Individualism measures the extent to which people feel independent and take care of themselves, as opposed to collectivism, which means being interdependent as members of larger wholes. Masculinity measures the extent to which gender roles are clearly distinct: men are supposed to be assertive, tough, and focused on material success, whereas women are supposed to be more modest, tender, and concerned with the quality of life. Uncertainty avoidance measures the extent to which a society is anxious and distrustful in the face of the unknown. Countries with a high uncertainty avoidance adopt stiff codes of behavior, guidelines, and laws and rely on the belief that only a single one truth exists. By contrast, a low score in this index shows more acceptance of differing thoughts or ideas. Long-term orientation measures the extent to which societies encourage thrift and efforts in modern education, considering it as a tool for preparing for the future. Countries that score low on this index are generally anchored to time-honored traditions and norms and view societal changes with suspicion. Indulgence measures the extent to which a society welcomes free gratification of basic human drives related to enjoying life and having fun. In particular, low score in indulgence is typical of countries that suppress gratification of needs and regulate it by means of strict norms.

Soyez [79] found out that the green behaviors differ cross country, in reason of the national culture. The national culture determines the salience of each value and, thus, it influences environmental orientation. According to Soyez [79], there is a cross-country substantial difference of pro-environmental orientation, for what individualistic cultures, such as Western ones, promote an eco-centric approach, whereas collectivistic cultures, such as Russian one, are anthropocentric and more interested in the benefits for future generations. Values are defined as "desired end-states that guide action and behavior of individuals' towards specific objects" [80, p. 178].

As a matter of fact, collectivistic cultures are those more willing to share scarce resources with members of the same group [80], differently from individualistic cultures.

In their work, Sreen *et al*. [80] found evidences that green behaviors are associated with collectivistic cultures and long-term orientations. Notably, prior findings proved that national cultures influence business organizations commitment toward eco-innovation in Europe [17].

Also, motivations are at the basis of intentions and green behaviors [30].

As a matter of fact, the byproduct of eco-innovation is the social value of the product.

The social value or benefit of eco-innovation is defined in terms of human needs. Such needs drive the motivation of eco-behaviors. Maslow [50], [51] proposed a hierarchy of human needs. These needs are articulated into five levels: physiological needs—those goods necessary for survival, such as water or food, safety needs—the need for security, belonginess—the need for being loved, self-esteem—the need for being esteemed and valued by others, and self-actualization—the need for doing good for others. As far as material and basic needs are satisfied, the human being starts desiring the next level status. Clift [14] argued that despite some eco-innovations may be considered as a material need, the social value can be defined in terms of self-esteem or self-actualization.

B. Eco-Innovation and Firms' Green Technology Management

According to Dresner [22], the term sustainable development was first used in 1980 with reference to well-being of people. Since then, this concept, which is often used as a synonym for eco- or green-innovation, rapidly evolved and assumed different nuances [5], [27]. So, we moved from the Andersen's [3], [4] conception of eco-innovation as the attractor of green rents to current idea of eco-innovations, as those "innovations that reduce the environmental impact of consumption and production activities" [27, p. 155].

By and large, prior research underscores the existence of different approaches to eco-innovation [4]. In this vein, Andersen [4] suggested a taxonomy of five categories of eco-innovation: add-on eco-innovations, integrated eco-innovations, alternative product eco-innovations, macro-organizational eco-innovations, and general purpose eco-innovations.

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Apparently, during the last two decades, scholars were paying an increasing attention to the debate on whether and how firms contribute to environmental sustainability through eco-innovations [6], [8], [28], [41], [61], [64]. According to Hellström [31], eco-innovation refers to a three-level process—technological, social, and institutional—aimed at developing new products/services that contribute to reduce the environmental burden. Notably, Hellström [31] argued that eco-innovation is supposed to build new social structures. In this sense, it should spring from radical disruptions. Nonetheless, most eco-innovations generated thus far are simply incremental. As a matter of fact, the firm's attitude toward eco innovation is shaped by its knowledge and culture [2].

At large, knowledge diversity within the firm is deemed the primary source of innovation [11]. When effectively managed, knowledge, along with persistent leadership, may foster ecological innovation [16], [46]. Knowledge, as the DNA of a firm, determines its resilience and orientation toward sustainability [7], [20]. Thus, firm's knowledge and culture largely influence the intention to invest in eco-innovation. Since the pioneer work of Thompson [84], the relationship between the bureaucratic structure and innovative behaviors was examined in the light of those conditions that psychologists identified as those most conducive to individual creativity. From a cross-cultural perspective, hedonic and utilitarian values linked to the perception of innovations are largely affected by contingency factors [49]. Thereby, the commitment to innovation can be considered as contingent of specific cultures, either in societal or organizational settings, as many scholars have previously demonstrated [58], [91].

Notably, Zhou *et al*. [91] suggested that indulgence strongly influences the individual utility function.

Indulgence is one of the six cultural dimensions proposed by Hofstede and Minkov [35] that precisely refers to "the degree to which people emphasize pleasure as opposed to duty" [91, p. 250]. A high-indulgent culture determines a pro-social behavior that emphasizes the importance of relational capital, cohesion, and collaborative behaviors [29, 52]. Also, indulgence is deemed to be relevant for the individual environmental concern [25].

C. Impact of Cross-Cultural Aspects on Eco-Innovation: The Eco-Innovation Index and R&D Expenditures in EU

Despite anecdotal evidences, there are few studies exploring how culture impacts the eco-innovation rate of firms [28]. Among the existing attempts, there is the study of Shane [75], who explored the impact of cultural values on innovation.

Shane [75] found that innovation rates may differ between countries because of the cultural values of their citizens. Thereby, cultural values may be a predictor of the innovation rate along with R&D expenditures. More recently, other scholars investigated the relationship between cultural dimensions and the degree of innovation at the national level [63], and they found that only three out of the six dimensions' scale actually matter: individualism, long-term orientation, and indulgence. Other studies, based on a multiple multivariate regression method and on the global innovation Index, found a positive relationship between innovation and individualism [66]. By and large, the most relevant studies on this theme often present conflicting or ambiguous evidences [10], [54], [76], [77]. Interestingly, none of these research works explicitly considered cross-cultural factors and their impact on eco-innovation, at both firms and national levels.

Differently, we assume that eco-innovation is strongly influenced by cultural factors.

As instance, the European Union is showing high sensitivity toward sustainability, proved by ad hoc, evolving regulations and continuous investments. Notably, EU developed a specific index to monitor environmental performance of its members: the eco-innovation index that is part of the Eco-Innovation Scoreboard (Eco-IS). The eco-innovation index uses six indicators grouped into five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency, and socio-economic outcomes.

Table I reports indicators for 2018 version of the index. This index is dynamic and changes over time. It is weighed per country population and normalized using a 0–1 scale and z-scores. Also, outliers are excluded. At the same time, EU is investing large amounts of public finance to support innovation. Part of this investments are dedicated to green innovation. These funds add up and work jointly with private business expenditures in R&D as a whole, and for green innovation specifically. According to Eurostat, the statistical office of the European Union, R&D expenditure in the EU increased slightly to 2.07% of GDP in 2017, and these funds were mostly spent in the business enterprise sector. Such data include either governments or firms' expenditures. Aforementioned statistic seems to contrast with some prior theoretical insights, arguing that the positive societal externalities of green innovation hinder firms from investing in sustainability [19]. Governments' R&D investments seem to be the key determinant of green innovation [62]. It is also proved that "green" R&D impacts positively both the environmental and financial performances of firms [15], [47]. Superior innovation performance is often driven by likewise superior knowledge management capabilities [21], [26]. Clearly, eco-innovation should be considered the strategic type of innovation, rather than the adaptive one. Henceforth, considering that R&D outsourcing is only effective when the underlying technology is easily codifiable and poorly strategic [38], eco-innovation cannot be outsourced without undermining the value creation capability of the firm.

Despite being sustainable apparently determines huge performance benefits, companies are still pretty reticent in terms of redesigning their business model for sustainability [70]. The missing tile, or the moderator factor, that could foster firms' sustainable innovation management may be stakeholder engagement [73]. In addition, the collaboration among government, industry, and university [71] may enormously help firms to overcome their inertia toward sustainability through joint R&D efforts toward greener businesses and society.

Finally, national culture may either hinder or promote such sustainable behaviors [19].

Hence, we hypothesize the following.

1) Hp1: R&D investments have a linear and positive effect on eco-innovation index.

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TABLE I
LIST OF INDICATORS IN THE 2018 VERSION OF THE ECO-INNOVATION INDEX

1. Eco-innovation inputs	
1.1. Governments environmental and energy R&D appropriations and outlays [% of GDP]	EUROSTAT
1.2. Total R&D personnel and researchers [% of total employment]	EUROSTAT
1.3. Total value of green early stage investments [USD/capita]	Cleantech
2. Eco-innovation activities	
2.1. Enterprises that introduced an innovation with environmental benefits obtained within the enterprise [% of total firms]	EUROSTAT / CIS questionnaire
2.2. Enterprises that introduced an innovation with environmental benefits obtained by the end user [% of total firms]	EUROSTAT / CIS questionnaire
2.3. ISO 14001 registered organisations [per mln population]	ISO Survey of Certifications
3. Eco-innovation outputs	
3.1. Eco-innovation related patents [per mln population]	Patstat
3.2. Eco-innovation related academic publications [per mln population]	Scopus
3.3. Eco-innovation related media coverage [per numbers of electronic media]	Meltwater
4. Resource efficiency outcomes	
4.1. Material productivity [GDP/Domestic Material	EUROSTAT
Consumption]	
4.2. Water productivity [GDP/total fresh water abstraction]	EUROSTAT
4.3. Energy productivity [GDP/gross inland energy consumption]	EUROSTAT
4.4. GHG emissions intensity [CO2e/GDP]	EEA
5. Socio-economic outcomes	
5.1. Exports of products from eco-industries [% of total exports]	EUROSTAT
5.2. Employment in eco-industries and circular economy [% of total employment across all companies]	Orbis
5.3. Revenue in eco-industries and circular economy [% of total revenue across all companies]	Orbis

Source: Adaptation from ec.europa.eu/environment/ecoap/indicators/index_en

2) Hp2: Indulgence has a linear and positive effect on eco-innovation index.
3) Hp3: Firm's R&D investments have a positive but smaller effect on eco-innovation than those of governments.

Also, European firms are mostly influenced by an individualistic culture. As prior studies indicated, there is a sort of conceptualization bias, for what new sustainable alternatives are often seen as simply more environmental friendly than their predecessors [31]. As the consequence, firms are mainly concerned with the possibility of cost saving linked to eco-innovation [12], [85]]. An antecedent study on the eco-innovation rate of European firms supported the evidence that access to subsidies and fiscal incentives has a slight impact on firm's orientation toward sustainable innovation [85]. Consistently, we assume that the contribution of firms to the eco-innovation rate is positive but scarcely significant.

III. METHODOLOGY

A. Research Background for Methodology and Sampling

Previous studies on innovation and green innovation largely relied on the use of Eurostat data [37], [45], [83]. Besides the reliability of such data, their open availability directly enables comparisons between studies [18]. In addition, prior studies often adopted various kinds of regression models [18], [40], [42], [87].

B. Data

Data concerning social development are taken from the Eurostat website. Let us recall that Eurostat is the statistical office of the EU within the European Commission, whose mission is to gather and offer statistics at the European level in various different areas, including economics, finance, society, industry, trade, transport, environment, and energy. It is widely recognized that Eurostat provides high-quality data, as it obtained the European Foundation for Quality Management "Committed to Excellence" recognition in 2016.

The data that we need for our analysis are available from year 2008 to year 2017 for all the 28 EU members. Nevertheless, data for Cyprus and Greece are very incomplete and thus we shall exclude these two countries, so that the dataset we consider comprises the following 26 EU members: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Spain, France, Croatia, Italy, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, and U.K. Moreover, for several of the aforementioned countries, few data are missing as well. Therefore, for each EU members, we take the average of every variable over the whole time-interval from year 2008 to year 2017, excluding those years for which data are not available. Finally, for each of the 26 countries, we considered the scores for the six aforementioned Hofstede's cultural dimensions.

C. Dependent Variable

To measure the performance of socio-ecological innovation at the country level, we use the so-called eco-innovation index

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TABLE II
VARIABLES

Symbol	Description
ECOINN	Eco Innovation index
GGERD	Gross domestic expenditure on R&D, Government sector [% of GDP]
BEGERD	Gross domestic expenditure on R&D, Business enterprise sector [% of GDP]
PDI	Power distance [Hofstede cultural scale]
IDV	Individualism [Hofstede cultural scale]
MAS	Masculinity [Hofstede cultural scale]
UAI	Uncertainty avoidance [Hofstede cultural scale]
LTO	Long term orientation [Hofstede cultural scale]
IND	Indulgence [Hofstede cultural scale]

(labeled ECOINN), which, quoting from the Eurostat website, "is based on 16 sub-indicators from eight contributors in five thematic areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency outcomes and socio-economic outcomes … [and] … is calculated by the unweighted mean of the 16 sub-indicators … [showing] how well individual Member States perform in eco-innovation compared to the EU average."

D. Independent Variables

The variables of which we want to test the influence on the eco-innovation index are related to the expenditure in R&D. In particular, for each country considered, we take both the R&D expenditure in the government sector (GGERD) and the expenditure on R&D in the business enterprise sector (BEGERD), measured in percentage of GDP. Quoting from the Eurostat, "the business enterprise sector includes all firms, organisations and institutions whose primary activity is the market production of goods or services [other than higher education] for sale to the general public at an economically significant price, and the private non-profit institutes mainly serving them." Further details can be found at the Eurostat website.

E. Control Variables

We control for a number of variables related to culture of the EU countries, which, together with the R&D expenditures, could affect the performances of each country in socio-ecological innovation. Specifically, we consider Hofstede's six dimensions of culture, namely power distance (PDI), individualism (IDV), masculinity (MAS), uncertainly avoidance (UAI), long term orientation (LTO), and indulgence (IND). For the reader's convenience, the variables employed are listed in Table II.

TABLE III
DESCRIPTIVE STATISTICS

	Mean	StdDev	Min	Max
ECOINN	90,990	29,404	34,500	135,625
GGERD	0,200	0,089	0,043	0,404
BEGERD	1,018	0,665	0,173	2,253
PDI	51,115	21,169	11,000	100,000
IDV	59,538	17,544	27,000	89,000
MAS	45,577	24,961	5,000	100,000
UAI	69,462	21,606	23,000	99,000
LTO	58,000	16,795	24,000	83,000
IND	43,192	20,034	13,000	78,000

F. Regression Model

To test our research hypotheses, we used the following baseline regression model:

$$\begin{aligned}\mathrm{ECOINN} = \beta_0 &+ \beta_1\mathrm{GGERD} + \beta_2\mathrm{BEGERD} \\ &+ \beta_3\mathrm{PDI} + \beta_4\mathrm{IDV} + \beta_5\mathrm{MAS} + \beta_6\mathrm{UAI} \\ &+ \beta_7\mathrm{LTO} + \beta_8\mathrm{IND} + \varepsilon \qquad (1)\end{aligned}$$

where the β coefficients are computed by standard OLS estimation. Following a common approach, all the variables in Table II are standardized, so as to be comparable with one another. Moreover, for comparison purposes, we also employed a generalized linear model (GLM) with the same dependent and independent variables as above, with logarithmic link function and with both the Gamma and the inverse Gaussian as family functions. In fact, after trying several different kinds of family functions (including the Gaussian and the power function), we found that the Gamma function and the inverse Gaussian function yield the smallest Akaike information criterion (AIC) and the smallest Bayesian information criterion (BIC), respectively.

IV. RESULTS

Descriptive statistics for all the regression variables are shown in Table III. As we may observe, ECOINN has a rather large variability among EU countries, since its minimum and maximum ranges are 34.5 and 135.625, respectively. The expenditure on R&D has a high degree of variability as well, since GGERD varies from 0.043 to 0.404 and BEGERD varies from 0.173 to 2.253. Table IV reports the (Pearson) correlations among the variables. In particular, we can show that ECOINN is positively correlated with both GGERD and BEGERD, which would suggest that the expenditure on R&D could have some significant effect on the ecological innovation performance. The results of the regression analysis are reported in Table V. First of all, we may observe that the regression is, on the overall, statistically significant, as the p-value associated to the F-statistics is smaller than 0.01. Moreover, the proportion of the variance of the dependent variable that the chosen independent variables are capable to predict is relatively high, as the determination coefficient R^2

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TABLE IV
PEARSON'S CORRELATIONS

	ECOINN	*GGERD*	*BEGERD*	*PDI*	*IDV*	*MAS*	*UAI*	*LTO*	*IND*
ECOINN	1								
GGERD	0,216	1							
BEGERD	0,781	0,224	1						
PDI	-0,598	0,179	-0,560	1					
IDV	0,391	-0,106	0,307	-0,565	1				
MAS	-0,151	0,065	-0,130	0,186	0,0580	1			
UAI	-0,438	0,243	-0,381	0,585	-0,1176	0,137	1		
LTO	-0,231	0,441	-0,101	0,146	-0,1352	0,095	0,076	1	
IND	0,735	-0,180	0,658	0,0120	-0,516	-0,079	-0,440	-0,402	1

TABLE V
LINEAR REGRESSION RESULTS

Variable	*B*
INTERCEPT	0
GGERD	0,383**
BEGERD	0,240
PDI	-0,202
IDV	0,056
MAS	-0,054
UAI	-0,094
LTO	-0,181
IND	0,399**
F-stat	8,382***
R^2	0,798
Adjusted R^2	0,703

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

TABLE VI
GLM RESULTS

Variable	*Gamma family* β	*Inv-Gauss Family* β
INTERCEPT	4,088***	4,079***
GGERD	1,415**	1,380**
BEGERD	0,104	0,111
PDI	-0,003	-0,002
IDV	0,002	0,003
MAS	-0,001	-0,001
UAI	-0,000	-0,000
LTO	-0,004	-0,004
IND	0,007**	0,007*
AIC	11,630	15,890
BIC	-54,556	-55,375

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

is greater than 0.7. Finally, we performed the Breusch–Pagan test for heteroscedasticity as well as the Jarque Bera test for normality. Both these tests did not reject the hypothesis that residuals are homoscedastic and normally distributed, which confirm the validity of the regression model.

As we may observe in Table V, the coefficient of GGERD is positive and significant (p-value < 0.05), which indicates that countries with a high governmental expenditure on R&D have also a high performance in ecological innovation. Instead, the coefficient of BEGERD, albeit positive, is not significant (p-value > 0.1), which suggests that the expenditure on R&D incurred by units in the business sector does only have a moderate impact on the eco-innovation index. Finally, the only cultural dimension that has a significant effect on ECOINN (p-value < 0.05) is the one related to indulgence. In particular, the regression coefficient of IND is positive, which has the following explanation: the indulgence dimension measures the extent to which countries pay attention to individual needs and to the quality of life. Thus, we can easily understand the positive and significant effect of the indulgence dimension on the ecological innovation performance if we think that countries scoring high in IND are also supposed to be concerned with the quality of the environment where citizens live.

It is interesting to observe that the results of the GLM, which are reported in Table VI, are perfectly in line with the above analysis. In fact, using either the inverse Gaussian or the Gamma family function, the only variables that are still found to have a significantly impact on the eco-innovation index are the expenditures in R&D in the government sector and the indulgence dimension of Hofstede's model.

V. DISCUSSION AND RESEARCH LIMITS

The results of the analysis confirm that R&D investments predict eco-innovation. However, eco-innovation is mostly driven by governments' investments, whereas firm's contribution is still poor. Many factors may impact this result. As instance, governments' may be less risk adverse and more long-term oriented than firms.

Also, evidences prove that eco-innovation is linked to cultural indulgence.

More precisely, the effect of indulgence on the eco-innovation index can be explained by the fact that the level of eco-innovation index increases when basic needs are already satisfied. As instance, the commitment toward green innovation may increase when firms have sufficient financial slack for financing innovation [55].

Differently from Shane [75], we found that indulgence is the most relevant cultural dimension for eco-innovation. However, as Shane [75] previously stated, cultural values vary over time. Our study also showed that the contribution of businesses to

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the national eco-innovation rate is modest. This result can be addressed based on various motivations. First, firms suffer from sunk costs linked to prior investments. The presence of sunk costs determines a coevolutionary lock-in an induce strategic inertia, leading to new investments avoidance, such in the case of eco-innovation. As a matter of fact, eco-innovation may disrupt firm's businesses. On the other hand, this kind of innovation is characterized by extreme risk and uncertainty. These factors, along with the conceptualization bias toward eco-innovation, may hinder firm's propensity toward sustainable innovation because of the fear of loss. In brief, the firm perceives eco-innovation as poorly rewarding or excessively risky.

The robustness of the employed method and the accuracy of the analysis provide strong results. However, there are some limitations. First, data are drawn from experimental statistics. Unfortunately, availability of this kind of data is still scarce. Second, the analysis is limited to EU countries. As the consequence, we have no insights on how the same phenomenon may unravel in different geographies. As other studies previously suggested [79], anthropocentric cultures may show a different pattern.

Finally, the adopted method offers information on mean level, which means that we are not able to catch and describe the over-time dynamic of the phenomenon.

VI. Implications

Notably, current study has a series of important implications. First, in line with the study of Shane [75], cultural values have proven to impact the innovation rate of countries. However, differently from the aforementioned research, we noticed that indulgence is the only relevant dimension in eco-innovation. Perhaps, it is because countries with highest rankings of the quality of life are also more eco-innovative than the others.

Second, this finding implies that there was a huge shift of cultural values in less than 30 years, from the Shane's study [75]. Probably, this is caused by the current attention toward global warming and pollution and by the fact that countries became wealthier.

Third, the analysis digs to light that cultural values should shape entrepreneurial orientation and firm's behavior toward sustainability. In particular, our findings suggested that firms operating in those countries with highest rankings of indulgence should invest in radical eco-innovation to fit with customers' needs.

In this vein, the study suggested that green behaviors may be incentivized by leveraging on the benefits for the environment.

Broadly speaking, firms shall invest in green technology management.

Thereby, differently from antecedent studies, we conclude that both culture and country investments matter for eco-innovation.

Another important implication concerns the radicalness of eco-innovation. In future, firms should increase their engagement in sustainable innovation projects if they want to meet customers' expectations and to be compliant with sovereign regulations. This imply a huge shift in the way firms should conceive eco-innovation: from a mere green washing to radical and effective environmental-conscious solutions. Engineering management plays a crucial role in this process. As a matter of fact, both firms and governments should invest to create ad-hoc units and educational programs to form human resources, who are specialized in environmental engineering and are able to face the sustainability challenge.

Finally, in line with the seminal study of Elkington [24], an important implication that follows the evidences presented in this article concerns the collaboration between public and private organizations for achieving an influential impact on eco-innovation. Policy makers should design new ways to stimulate firm's sustainable orientation rather than offering mere monetary and fiscal incentives. Since governments are leading the chase to eco-innovation, incentivizing collaborations between public and private actors is the most effective way to increase the eco-innovation rate of a country and to put back on track firms' investments.

VII. Conclusion

This article contributes in different ways to advance the knowledge in the field of green innovation management. Differently from prior studies, we focused on the social dimension of eco-innovation and we provided a better understanding of green innovation management. We originally integrated the cross-cultural perspective into the R&D policy of European firms and governments.

First, according to our results, country indulgence has a positive impact on the eco-innovation index. In brief, the wealth of a country may predict its positive environmental attitude: the more people were satisfied, the more they were attentive toward the environment. As the consequence, increasing levels of indulgence seem to be correlated with increasing levels of eco-innovation.

On the one hand, this result explains why some countries, such as developing one, are less eco-effective. On the other hand, though, an effective management of green innovation could become a key enabler for growth.

Then, we provided extensive evidences of the impact of R&D expenses of businesses and governments on eco-innovation. The study explains that governments' investments in eco-innovation are more effective than those of firms.

As the consequence, firms' decision makers are called to rethink the role of green innovation management, by avoiding fake greenery and investing in groundbreaking eco-friendly novelties. Yet, policy makers should find more effective ways to stimulate firms' green innovation.

In addition, we dig to light that it exists a firm's bias in conceptualizing eco-innovation that impacts the radicalness of novelties and determines a marginal impact on sustainability.

Finally, we noticed a rapid evolution of cultural values over three decades. With this regard, firms mostly behave as laggards, since they appear to be less sensitive to sustainability values than governments.

Future research should extend and corroborate our findings by replicating the analysis in non-EU Countries, especially in those collectivistic countries that are more interested in benefits for the humankind as a whole.

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Besides, while other disciplines, such as engineering management, already dedicate a large space to environmental sustainability, there are relatively few managerial scholars in the field of innovation occupied with studying eco-innovation [72]. So, prospect managerial scholars should pay more attention to green technology management by investigating what are the drivers of eco-innovation and how it impacts the wellness of society. Green technology management gained strategic relevance only recently. This new field of study is mostly underexplored, but it appears as highly promising. Future research should focus on this new area to provide useful tools for managers and a meaningful impact for society as a whole.

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