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Carrots or Sticks: Which Policies Matter the Most in Sustainable Resource Management?

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Abstract: Green growth has resulted from resource management, setting the speed for sustainable development. Eco-innovations are essential for the improvement of a firm's performance with societal gains, demanding special attention from policy makers. This paper deals with the effect of policy actions on the enhancement of eco-innovation adoption. The Community Innovation Survey (CIS) 2012–2014 is used to estimate the impact of 'carrots' and 'sticks' on innovations with ecological benefits. In addition, the impact of a firm's structural characteristics in ecological strategies is investigated. Regulations and taxes enhance eco-innovation, but grants are only relevant in the case of eco-innovations with external benefits. The firm dimension and non-technological innovation also increase the eco-innovation propensity. Embedding policy actions with environmental concerns will enhance social responsibility and promote resource preservation, providing waste as an economic value. The purpose of this paper is twofold. First, it aims to appraise the effectiveness of the different policy instruments applied in the adoption of innovation with ecological benefits with both internal and external benefits. Secondly, it aims to identify which firm characteristics determine these managerial strategies. Hopefully, light will be cast on the topic so that public and private decision-makers will be given recommendations for policy package design working towards smart and green growth.

Keywords: resource management; public policy; sustainability-oriented innovation; eco-innovation; Community Innovation Survey; logit models

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1. Introduction

Achieving a prosperous and healthy environment depends on the development of an innovative, digital, and circular economy where nothing is wasted; natural resources are sustainably handled; and ecosystems are preserved, valued, and rebuilt to ensure a human-centered and resilient civilization. Preserving natural resources, including both raw materials and the ecological environment, requires government intervention given the nature of public goods. This allows the promotion of productive and inclusive prosperity relying upon efficiency gains, promoting the vitality of the ecosystems. The future must focus on individuals, so scarcity needs to be further addressed.

Innovation is the catalyst of sustainable development and the foundation of technological transitions. The future is digital and demands innovation-driven frameworks; data-based technologies; technology combination; blurring the lines between physical, digital, and biological spheres; and fostering societal prosperity [1]. This brings hope for resource management vis à vis the elimination of waste and the implementation of smart production chains endorsing an effective demand and customized preferences [1,2].

The environmental pressure and exponential resource depletion that have occurred over the past few decades in the European Union have resulted in a broad range of environmental legislations. Regulations have constrained or prohibited the use of several substances considered toxic or hazardous. As a result, air, water, and soil pollution has significantly fallen, and EU citizens enjoy some of the best air and water qualities in the world. Additionally, nearly one fifth of the territory is protected natural areas [2], reinforcing the pertinence of policy actions.

Fast changing production and consumption patterns promote rapid economic growth. However, these engines of growth are accompanied by the exponential depletion of natural resources, energy over-consumption, environmental damage, and waste. This modus operandi is incompatible with the sustainable development goals (SDGs) and the promotion of the ecological environment [3].

Green innovation plays a central role in the promotion of sustainable and inclusive growth; it encompasses, on the one hand, resource preservation, further reinforcing sustainable development, and on the other hand, promotes innovation, which generates prosperity. Consequently, this binomial enhances development, promoting virtuous cycles of innovation respecting resource preservation with environmental benefits [4,5]. The Brundtland report set out a new era for environmental issues, advocating the urgent need for prosperity achievement along with global cohesion, and protecting the legacy for future generations [6]. These topics dominate the policy agenda worldwide. Extant literature considers innovation to be a driver of economic and social prosperity on both the micro- and macroeconomic level due to its ability to generate comparative advantages [5].

Over the last few decades, the sustainability concept has grown in popularity, and consequently, sustainable development is recursively mentioned. Sustainability-oriented innovation has gained relevance in the innovation literature [7] as a response to this trend.

Environmental hazards, climate pressure, resource over-consumption, ecological depletion, and social inequality have accelerated the shift towards a more sustainable ecosystem. Global concerns about environmental, social, and economic sustainability are now part of the policy-making strategies [8]. Consequently, firms must accommodate a new sort of consumer, with an increased awareness of ecological issues and ecological policy regulations.

Sustainability is an important factor in a firm's operation, often being adopted as a pillar of corporate social responsibility [9]. Evidence proves that resource preservation and economic development are compatible; however, so far, policy recommendations have failed to be strong enough to promote ecological behavior as a rule, rather than an exception [10].

Eco-innovation needs to be addressed by policy actions in a structured way, as it is considered a driver of the environmental and innovative performance, generating more sustainable business models. Its adoption boosts success and creates competitive advantages [11–13]. Nevertheless, this challenge is not relevant for all organizations [11].

An increasing number of OECD (Organisation for Economic Co-operation and Development) governments consider eco-friendly innovation to be the major driver of green growth [14]. Environment-related policies represent an important response to contemporary challenges, such as climate change and energy safety, being the building blocks of competitive advantages in the environmental assets sector [15]. This further reinforces the importance of stimulating environment-benefiting innovations [14].

The boundaries of eco-innovation are blurry, and the concept is hardly definable, due to the multiplicity of proposals emerging from different countries and organizations. In terms of the OECD standards, eco-innovations are innovations which positively impact the environment [14]. However, the European Commission states that eco-innovation is an innovative practice which reduces environmental impacts along with optimization of the allocation of resources in the product lifecycle, being radical or incremental and technological or non-technological. It may emerge from a multiplicity of contexts, in which the environmental performance may be a side-driver, and, it does not always relate to high-tech solutions. Notwithstanding, these innovative actions aim to work towards sustainable development, so this new knowledge application generates ecological benefits [16].

Policy actions addressing environmental issues must be intertwined with other domains requiring multiple layers of appraisal, including duration and accomplishment, institutional control, public and private sector enrolment, industrial competitiveness focus, and effective technology transfer [12]. The European guidelines for application in European countries promote eco-innovation relying on the supply-side, focusing on the availability of public grants to finance R&D activities; conversely, in non-European OECD countries, the target is the demand-side, promoting performance standards [14,16].

According to the OECD Green Growth Strategy [15], policies for promoting innovation should be encouraged, as these actions may increase efficiency levels in the management and exploitation of natural resources, fostering the emergence of heterodox economic opportunities that further reinforce greener activities.

The widespread diffusion of innovation practices with ecological benefits will improve environmental conditions, as well as resource preservation. This will generate positive spillovers in terms of both the economic and social dimensions, generating synergies among innovation ecosystems [10,11]. Persistence of these actions will permit a long-term and irreversible shift to a greener economy [15].

Emerging economies are increasingly suffering from the pressure of efficient resource management and their growth strategy must encompass green strategies, boosting productivity levels while preserving resources and promoting long-term sustainable development [14,15]. Given the importance of environmental issues and resource management, most OECD countries have built national strategies to promote green growth in a systematic way, reconciling economic and environmental targets [15]. Policy packages must consider the importance of persisting with these actions to give the future a chance. Creating opportunities for open cooperative systems along with competition enables the survival of innovation ecosystems [17]. Moreover, the development of persistent innovation spells will reinforce the virtuous innovation cycles and consolidate the advantages for future innovations [18].

In 2020, Portugal became a Strong Innovator. Over time, its performance has increased in relation to 2012, moving from 16th to 12th place on the European Innovation Scoreboard. The strong increase in 2018 is almost entirely explained by its improved performance regarding the indicators using Community Innovation Survey (CIS) data. The major strengths of the Portuguese System of Innovation relate to the ecosystem, the research system, and the entrepreneurial innovation levels. Conversely, the weaknesses relate to the absence of equity and venture capital in Research and Development (R&D), as well as patenting and exports in Knowledge Intensive Business Services. Notwithstanding, there has been an important increase in the overall innovation ecosystem, from private firms to public and private R&D labs [19].

Unfailing eco-innovative activities seem to require relying on a broader set of external sources of knowledge than traditional innovation processes. As a consequence, the incorporation of external players in innovation activities and the promotion of open innovation dynamics will reinforce the path towards sustainable development [14,15,17].

Notwithstanding, OECD governments are increasingly trusting environmentally-related taxes as efficient tools, given their deterring effect on misconduct. Indeed, taxes are one of the most effective policy instruments for disciplining polluters; however, these actions promote technological stagnation and cleavages between Small and Medium Sized enterprises (SMEs) and lager firms. Moreover, in inelastic demand scenarios, the tax burden is transferred to consumers [14,15]. However, innovation is credited as an efficient solution for environmental problems, encouraging the shift towards cleaner and safer technologies. As a consequence, policy actions should also encompass incentives for innovation, providing positive rewards for those conducting the transformation [12,20].

In addition to the achievement of sustainable development being multidimensional and complex, it demands for the serious involvement of individuals and institutions. This topic was addressed by Elkington, who proposed sustainable businesses as the challenge of the 21st century [21]. Elkington argued that this should rely upon the sustainability performance, delivering the foundations for sustainably-oriented innovation. To do so, the author employed the Triple Bottom Line model, defining three pillars: Economic prosperity;

environmental quality; and social justice. These vectors are interrelated, interdependent, and conflicting, pushing businesses towards deep transformation, which is the present challenge for policy makers.

The analysis of the different policy instruments in eco-innovative propensity is the first element of originality of this article. A second element of originality is the combination of endogenous and exogenous drivers of eco-innovation adoption. A third original aspect of this article is the econometric strategy, dividing the eco-innovations according to the benefits produced (internal or external), enabling the establishment of the most effective match between the policy instrument and the expected outcome. Lastly, this study covers the Portuguese case, which depicts a transition case from a Moderate Innovator to Innovation leader, which can be used as good practice for other economies.

The remainder of the article is structured as follows: Section two proposes a theoretical framework, connecting the relevant concepts; the third section depicts the methodology, database and sample, variables in use, and estimation methods; then, the results are presented and discussed; and lastly, conclusions, limitations, implications, and policy recommendations are presented.

2. Theoretical Framework

2.1. Sustainable Resource Management

The concerns related to environment and ecological issues have been in the EU agenda since the mid-1970s, and environment policy packages are built upon action programs identifying major targets to be achieved during a time frame [20,22]. The Research and Innovation Observatory Report highlighted five pillars of the policy making strategy in Portugal: Improvement of firms' innovative performance relying upon the technological and managerial capabilities; support of start-up creation in high-tech sectors; construction of solid innovation networks to enhance knowledge transfer involving academia and industry; development of multi-layer agendas on innovation policy intertwining with other fields of action; and reinforcement of the stock of human capital inside firms [22]. Even though none of them are directly connected to eco-innovation, there is an expectation that their combination, along with the market pressure, will lead to innovative actions in the search for environmental benefits.

The sustainability-oriented innovation conceptual framework forces firms to intentionally change their philosophy and values and general involvement in corporate social responsibility. As a result, products, processes, and practices will be developed with the target of social value creation, along with increased economic returns. These practices will lead to improvements of the product and/or service quality, resulting in financial returns, a higher market share, and a sustainable growth pattern [23,24]. As a consequence, sustainability targets are strongly connected to the adoption of eco-innovations, given their respect for the environment and their requirements in terms of efficient resource management [25], and apply to goods, services, processes, or business models [14]. Policy initiatives implemented worldwide by leading institutions and governments have forced firms to gain an awareness of the potential benefits of improving the environmental efficacy and the reduction of environmental pressure obtained through innovation [25].

The mainstream definition of sustainability-oriented innovation states that related actions rely on intentional change in a firm's philosophy and ethics, as well as the transformation of its products, processes, and overall practices, in order to meet the purpose of generating social and environmental value, in addition to economic returns [23].

A further development of this concept establishes a framework [26] proposing three main vectors of action. The first is sustainability-relevant innovation, which occurs when an innovation results in a positive aspect external to the environment, despite additional value not being the main purpose of the innovative action; however, as it generates external benefits, it should be encouraged. However, this type of innovation may sometimes neglect social sustainability and governance dimension. The second is sustainability-informed innovation, which fosters innovation processes not targeting sustainability issues, despite the effort of the producer to meet sustainability objectives during its development, production, and use. Finally, the third is sustainability-driven innovation, which relates to an innovation deliberately focusing on the sustainability goal. In this case, innovation occurs, first and foremost, to solve a societal and/or environmental problem.

Sustainable resource management combines the contributions from both environmental economics and innovation studies, and focuses on the drivers of eco-innovations, which may be grouped as "market-pull", "technology push", or "regulation effects" [27,28]. Eco-innovations are consequently the natural response to an emerging demand for eco-products [29].

2.2. Ecology-Driven Innovation

There have been plenty of attempts to define ecology-driven innovations (e.g., [14,15,25,30]). Regarding the mainstream aspects, eco-innovation consists of the development and exploitation of a product, a productive process, a service, or an organizational method, new to the firm, leading to enlargement of the product life cycle and a reduction of the environmental risk, pollution levels, or misleading resource allocation compared to extant alternatives.

Green innovation focuses on achieving economic development along with environmental ecology and resource preservation, energy saving, and the efficient allocation of endowments. It is argued that it must reduce or eliminate environmental damage through the implementation of new and smart productive processes, digital technologies, responsible products, and efficient systems or organizations [3]. It pushes forward the technological frontier elevating the efficiency in the use of natural resources, promoting economic development and environmental protection [4]. A careful analysis of environmental impacts is required to control existing practices and to force organizations to work towards the achievement of green growth-driven technological innovation [5].

In doing so, green innovation will force firms to internally improve, in both the economic and environmental domains, while minimizing the sunk costs of the innovation process by means of external knowledge transfer [31]. This process will generate a twofold effect, as firms will enhance their competitiveness while promoting environmental sustainability, solving a double market failure. As a result, there will be knowledge generation and resource preservation, making environmental regulations pivotal in its promotion [32].

An analysis of the United States, between 1983 and 1992, permitted the identification of a positive association between pollution abatement pressures and eco-innovation in manufacturing industries [33]. Information from the Eco Innovation Observatory encompassing eco-innovation data for all EU members from 2008 to 2013 proved that policy stringency, measured as the degree to which countries implement regulations to force industry to develop environmentally friendly production processes, does not determine the eco-innovation performance [34]. Moreover, countries in which there is a significant cost increase for breaking environmental rules perform better in terms of eco-innovation. Therefore, taxes could be used to discipline eco-innovative behavior, naturally increasing firms' costs and pushing forward the eco-innovation performance, since firms would then acknowledge these ecology-driven processes as a tool for avoiding further increases in the costs of production [35].

H1: *Policy withholders such as taxes or regulations increase the adoption of eco-innovations.*

To date, the literature has been dominated by a technically-focused, product-oriented view of innovation, promoting incremental adjustments to meet environmental challenges [23]. All in all, cleaner production is defined as "the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment" [36]. Thereby, these innovations "reduce the environmental impact caused by consumption and production activities, whether the main motivation for their development or deployment is environmental or not", being either the result or the process itself [10]. Therefore, cleaner production emphasizes minimizing the environmental impact and eco-efficiency emphasizes economic gain. The outcome of applying both inside the firm may be the same [37], but it is harder to verify an environmental motivation than an environmental outcome [38], which is a determinant for effective public policy construction.

H2: *Policy enhancers such as grants increase the voluntary adoption of eco-innovations.*

Tackling the process is complex as results differ among countries, proving how difficult it is to develop an efficient public policy to promote eco-innovation. In most cases, regulatory compliance costs have a positive effect on the patenting of environmental technologies [34,37]. Additionally, the disincentives for R&D produced by a command-and-control approach to environmental regulation may be exceeded by the high returns that regulation creates for new pollution-control technologies.

Despite lacking a one-off policy strategy, innovation with ecological benefits continues to be implemented and is gaining momentum as a business opportunity, balancing standardization and customization or mass personalization. In the short run, there is a natural increase in the cost structure; still, it is worth implementing in the long run [34,38].

Market pressure and the user community are critical for ensuring a broad implementation of eco-innovation. Consumers are now more aware of the environmental emergency and support organizations doing less harm to the environment; notwithstanding, the design, price, quality, and performance should never be relaxed by the producers [23,38].

2.3. Innovation Performance and Policy Actions

Environmental economics literature emphasizes the key role played by environmental regulations in stimulating eco-innovation adoption [29,34]. Innovation literature focuses on the supply-side factors of eco-innovations, such as firms' organizational capabilities, and demand-side mechanisms, such as customer and societal requirements for corporate social responsibility (CSR). Moreover, management literature focuses on CSR policies that consolidate firms' mission statement strategies through increasing investments in eco-innovation (e.g., [39,40]).

Promoting an innovative environment in which the co-creation of value and sustainability principles is developed inside the value chain with the enrolment of the user-community is a challenge for the future. In this new framework, stakeholders are actively involved in value creation [41] and firms develop assets addressing the targets of the sustainable development goals [42]. Most institutions and organizations now have an awareness that sustainable innovation is the only way to achieve sustainable development in the twenty-first century [23,43].

Demirel and Kesidou [44], through a detailed empirical analysis of 289 UK firms that responded to the 'DEFRA Government Survey of Environmental Protection Expenditure by Industry' in the years 2005 and 2006, measured the impact of different policy instruments on three eco-innovation types (end-of-pipeline pollution control technologies, integrated cleaner production technologies, and environmental R&D). Their findings evidence that command-and-control approaches, such as environmental regulations, affect end-of-pipeline pollution control technologies and environmental R&D, but do not influence integrated cleaner technologies. Contrarily, market-based instruments, such as environmental taxes, do not have a significant impact on any of the three types of eco-innovation. Moreover, environmental R&D is not only stimulated by regulation, but is also market driven, mainly motivated by the cost saving potential of the outcomes that arise from environmental R&D.

Analysing the German CIS conducted in 2009, Horbach et al. [45] found that it was possible to distinguish public policy effects regarding present regulations, anticipated future regulations, and the fulfilment of norms and standards. Present regulations are only significant for air, water, soil, and noise emissions. Although material and energy saving technologies lead to cost reductions, these benefits have not been proven to be fair enough with the actual policy. For dangerous substances, noise reduction technologies, water and soil protection, and cost savings do not play a positive effect. This gives a strong signal on the need to improve command-and-control regulations. The analysis, based on subsidies, reinforces their importance to energy and emission reduction products. Conversely, this instrument has a negative correlation with recycling practices. Regulations are far more important for eco-innovations than for other types of innovation.

Once more for the German case, using a survey on environmental policy tools for manufacturing firms in 2003, it was proved that none of the policy instruments analysed (market-based and command-and-control) seem to have a significant impact on firms' pollution intensity. In contrast, policy stringency positively impacts eco-innovation and abatement activities [46].

Later on, Horbach et al. [47], using CIS data for a cross-country analysis of French and German industrial firms during the years 2002–2004, found that, in both countries, the regulatory push–pull effect resulting from the implementation of environmental policy instruments is highly relevant for eco-innovations. However, subsidies failed to reach statistical significance for eco-innovations in any of the countries.

In Italy, Mazzanti et al. [48] also found that grants, in addition to policy-driven environmental costs, have a positive impact on firms' eco-innovative behavior. In the United States, a positive association between pollution abatement pressures and eco-innovation was found for manufacturing industries for the 1983–1992 time frame. It is highlighted that market-based instruments, such as environmental taxes, do not have a significant impact on any of the three types of eco-innovation. Additionally, environmental R&D is not only stimulated by regulation, but is also market driven, mainly motivated by the cost saving potential of the outcomes [33].

In the context of rising prices of natural resources, scarcity, and dependency on imports [35], the European competitiveness and capacity for sustainable growth will depend on improvement of the resource efficiency. As firms start eco-innovations to satisfy an ecology-driven demand, as well as the societal requirements, higher order investments in eco-innovations are stimulated by other factors, such as cost reduction, organizational capabilities, and stricter regulations [49,50].

Environmental policy sets out commitments to improve the implementation of existing legislation and to secure further pollution dumping. It provides a long-term vision of a non-toxic environment while enhancing the investment in knowledge to encourage innovation and the development of more sustainable solutions [42].

Considering regulation and cost reductions as being the major drivers of these innovations, the most efficient policy package needs, on one hand, to support eco-innovations on the supply side by means of investments in innovative activities and technological improvements and, on the other hand, to create demand for the emergent products and services. It follows that policy makers should consider both the demand and the supply side with instruments that work as either enablers (carrots) or withholders (sticks).

Different frameworks on eco-innovation determinants have been developed over the years, including demand side and supply side, regulation, and policy determinants, e.g., [16,48–56]. Internal and external factors, along with the characteristics of the environmental technologies, have been highlighted [52]. All in all, the structural characteristics of firms, business logic, technological competence, firm's environmental strategy, and marketing innovation have also been found to be relevant [56]. Eco-innovation is triggered by a combination of internal and external drivers. However, in super producers, such as China, the external pressures arising from foreign environmental regulations, the green international demand, and competitors affect eco-innovation both directly and indirectly. Firms are forced to have an integrative capability for eco-innovative responses combining internal and external sources [57].

It seems that the regulatory push/pull effect caused by environmental policy-specific instruments (taxes and licenses) is overestimated. Relevant elements of successful environmental policy, such as long-term goals and targets, policy-mixes, heterogeneous policy actions, and the set of agents in the innovation ecosystem, are seldom considered by policy makers [25]. If the market forces do not severely punish harmful environmental impacts, the competition between environmental and non-environmental innovation will be distorted. This relies on the fact that externalities cause the under-provision of investment in environmentally friendly technologies. Additionally, the regulatory framework will play a major role in the promotion of generalized eco-innovative behavior among firms, households, and other institutions.

2.4. Structural Characteristics of Firms Affecting Eco-Innovation

Based on previous contributions, this study includes additional structural characteristics of firms, consisting of the technological regime and size, open innovation engagement, and skill intensity; managerial strategies, such as demand pull or cost push; and finally, public policy instruments [58–60].

According to the literature, firms can adopt one of the four technological trajectories; however, those classified as "market-oriented innovators" engage significantly more in eco-innovation. These organizations use "formal appropriability mechanisms", "market opportunity recognition" arising from cooperation, and high knowledge cumulativeness [35,61].

H3: *Firms included in high-tech regimes are more likely to eco-innovate.*

H4: *A higher skill intensity leads to a higher probability of eco-innovating.*

In another stream of the literature, analysis of the firm dimension is given a major role in the explanation of eco-innovative propensity. In this case, smaller firms are identified as less prone to engage in environmental actions compared to their larger counterparts. Moreover, the empirical evidence suggests that these smaller organizations usually engage in environmental innovation in order to meet regulations [62]; however, there is a small group undertaking proactive actions working towards environmental innovation with positive financial outcomes [63]. Assuming rationality in their behavior, firms will adopt environmental practices if there is a financial gain, in the same vein as they do with other innovation types [64]; consequently, it seems that not all companies benefit from environmental innovation to the same extent.

Very often, a general innovative strategy and the firm dimension are identified as eventual moderators in the relationship between environmental innovation and the firm's performance [64]. The impact of subsidy-induced environmental innovations seems to be insufficient in smaller organizations. However, an individual analysis of the policy effect is needed to provide a more precise picture of reality, moving then to eventual generalizations, and verify whether subsidies actually outweigh the costs involved in developing eco-innovation [65,66].

H5: *Larger firms are more likely to adopt eco-innovations.*

On the other hand, smaller organizations should adapt their innovative strategies to their customers' tastes, preferences, and overall engagement with ecological causes. In most cases, eco-innovation is not separated from other innovation types playing a complementary role. As clients determine a small firm's survival and performance, meeting their expectations with new, environmentally friendly goods or services will positively affect the financial performance [64,67].

H6: *Performing other types of innovations increases the likelihood of eco-innovation, but the effect varies, according to the nature of the innovation.*

H6a: *Non-technological innovations increase the likelihood of eco-innovation adoption.*

H6b: *Technological innovations increase the likelihood of eco-innovation adoption.*

Recent evidence proves that, as happens for other innovation types, eco-innovation benefits from an open innovation mode [68,69], in which the knowledge boundaries between firm and external ecosystems become permeable. The development of new goods and services or technologies through adaptive networks is an ideal framework for eco-innovative organizations, especially if they are small or medium sized. These organizations have an additional pressure, as there is a need to quickly internationalize and present customers with new green technologies, allowing enlargement of the market share [70]. Thereby, policy-makers should provide an accurate context so that firms can consistently adopt eco-innovative behaviors based on the use of external knowledge [69,70].

An open framework of knowledge sourcing demands special attention in the case of ecologically-driven innovations, as attention should be paid to the extent to and diversity with which firms draw on external knowledge providers [17]. Inside the innovation ecosystem, the choice of the optimal knowledge partner becomes a crucial stage, as misleading connections will deter contact efficacy. Deep and sustained interactions will generate benefits, and even if the purpose is not 'green', in most cases, due to efficiency gains, it will enhance the environmental performance by means of the technologies adopted. However, cooperative innovation networks seem to work more effectively for ecological innovations than for other types of innovations [68]. Eco-innovation is related to R&D initiative and knowledge capital endowments [54], organizational practices, and management schemes [69]. Concerning the regulatory effects, extant literature has identified environmental standards and policies as leveraging its adoption, further creating markets for eco-innovators [70,71].

H7: *Engagement in open innovation positively impacts the probability of eco-innovating.*

When considering eco-innovation with a systemic nature, firms must deal with plenty of techno-economic problems, which demand different types of knowledge and interactions [72]. Following Carrillo-Hermosilla et al. [38], eco-innovation leads to a four-dimensional shift encompassing 'design', 'users' involvement', 'product-service', and 'governance' dimensions. Knowledge sourcing has a different impact on the propensity and extension of eco-innovation adoption [73]. While intensive interactions appear generally beneficial, given that they are acquired with external knowledge, their management may become difficult, which may discourage firms from adopting them [74]. Extending the diversity of eco-innovation, based upon external knowledge sources, will generate benefits, but it is strongly connected to the sectors of activity [75,76] and innovation types [77,78]. Broad and deep sourcing strategies increase the eco-innovation potential. These projects may be developed by firms or non-profit organizations and can be traded on markets, and their nature can be technological, organizational, social, or institutional [25]. Notwithstanding, there seems to be a close connection between the organizational links, the type of innovation performed, and their activities, leading to the design of particular networks in the promotion of eco-innovations [78,79].

3. Materials and Methods

3.1. Database

The analysis was performed using data collected from the 'seventh wave' of the Portuguese Community Innovation Survey (CIS) carried out in 2014. This broad survey is part of a periodical effort of the statistical agency of the European Union to appraise innovation activities across several European countries, following the OECD guidelines for innovation surveys (methodological details concerning the Portuguese edition of the CIS can be found in https://estatistica.dgeec.mec.pt/docs/docs_dm/DMet_CIS2016_final.pdf). In this particular case, the survey gathered information regarding innovation activities led by firms during the years of 2012–2014, in Portugal. This is the most recent wave of the survey encompassing the eco-innovation topic, as the CIS2016 and 2018 do not focus on these aspects of innovation. Following the methodological design, the survey does not keep all the relevant questions fixed, and, in this particular case, questions addressing eco-innovations are only included for the 2012–2014 period; as a consequence, only cross sectional data analysis, rather than a panel, is feasible. The empirical part of the research will be presented in the section "Innovations with environmental benefits", providing a comprehensive picture of the eco-innovation practices for the Portuguese case, which will approach the case of a small moderate innovator. The CIS14 encompasses

7083 firms belonging to different economic sectors (more detailed information about the overall results of the Portuguese performance in terms of innovation practices can be found in https://www.dgeec.mec.pt/np4/207/%7B$clientServletPath%7D/?newsId=113&fileName=Principais_Resultados_CIS2014_29092016.pdf).

The empirical analysis included an exploratory section, followed by statistical testing, and lastly, the econometric estimations. The survey collected evidence from firms with 10 or more employees located in all Portuguese regions. It includes firms operating in the primary, secondary, and tertiary sectors and covers the three-year period preceding the survey (2012–2014). Despite the existence of multiple questions covering a variety of topics in innovation, here, the focus is placed on questions concerning the innovation types, firm dimension, economic sector, human capital, sources of information and collaborations established to innovate, public policy actions, and innovative strategies.

This survey is widely used by academics and data from other countries have been analyzed from multiple angles and relating to different questions (e.g., [17,50,54–56]). The CIS encompasses limitations. Firstly, the variables are based on self-reported information, which could be less objective than exogenously collected data, such as the number of patents or CSR rankings. Secondly, the CIS dataset does not allow the economic impact of eco-innovations to be evaluated, which is a determinant for firms adopting an environmentally friendly performance.

3.2. Research Methods

As the eco-innovative propensity is a latent variable which relies upon an observable variable (performing eco-innovations with internal or external benefits or both) which takes either the value 0 or 1, depending on the firm behavior, the most accurate model for running the estimation is the logit model.

The dependent variable, in general terms, is the adoption of eco-innovations. However, underlying motivations of these actions may be the search for internal or external benefits. As the drivers may differ, methodologically, the option was splitting the entire sample into two sets of models with different instruments. In a second step, policy instruments were identified and included as predictors. As a consequence, two different with-holders (environmental regulations and environmental taxes) and one enhancer (public grants) were considered. The effect of each policy was appraised by means of a one-off effect caused by a single instrument; this procedure avoids the potential biasedness caused by multi-instrument collinearity. For these reasons, nine models were produced, considering the three dependent variables and the three policy instruments.

Therefore, the effect of the policy instrument on the dependent variable was controlled by a set of firm structural characteristics affecting the former, previously identified in the literature. Once more, reinforcement of the robustness in the estimations led to the inclusion of unchanged predictors in all of the models run, allowing for inter-model comparisons.

3.3. Variable Description

Table 1 describes the variables in use, according to their measurements, as well as the meaning of each of the possible outcomes. From the given definitions, dependent variables are binary, and the predictors are both scales and multinomial ordered effects. Therefore, the estimations provide the effect on eco-innovative propensity caused by a caeteris paribus change of state or level change.

Table 1. Variable description.

Variable	Description	Type
ECO_external_ben	1 = the firm did perform innovation with external environmental benefits; 0 = otherwise	Binary
ECO_internal_ben	1 = the firm did perform innovation with internal environmental benefits; 0 = otherwise	Binary
ENGRA	0 to 3 scale regarding the importance of the government grants, subsidies, or other financial incentive factors in the EI introduction	Multinomial
ENETX	0 to 3 scale regarding the importance of the existing environmental taxes, charges, or fees factors in the EI introduction	Multinomial
ENEREG	0 to 3 scale regarding the importance of the existing Environmental Regulations	Multinomial
TECH_REG	1 = Supplier Dominated; 2 = Scale Intensive; 3 = Supplier Specialized; 4 = Science-Based ([80])	Multinomial
INNOV_TECH	Firm performed a product or service innovation (1,2 different types); 0 = otherwise	Count
INNOV_NON_TECH	Firm performed a process, organizational, or marketing innovation (1,2,3 different types);0 = otherwise	Count
OPENINNOV	1 = Firm engaged in both in-house R&D and external R&D; 0 = otherwise	Binary
SIZE	Firm dimension based on the number of workers (1 = Small; 2 = Medium; 3 = Large)	Scale
EMPUD	0 = 0% employees with a tertiary degree (TD); 1 = 1% to 5% employees with a TD; 2 = 5% to 10% employees with a TD; 3 = 10% to 25% employees with a TD; 4 = 25% to 50% employees with a TD; 5 = 50% to 75% employees with a TD; 6 = 75% or more employees with a TD.	Scale

4. Results

4.1. Exploratory Analysis

Table 2 reports the descriptive statistics and the pair-wise Pearson correlations for the variables included in the regressions.

The analysis of the coefficients of the correlation matrix reinforces the inexistence of collinearity problems among the variables in use. Indeed, kurtosis' values point towards a platikurtic distribution of all variables, which may reinforce the importance of the tails, and the potential existence of outliers. Additionally, the Variance Inflation Factor (VIF) result is around 1, which is far below the commonly accepted threshold, eliminating any potential multicollinearity problems in the regression [81].

4.2. Econometric Results

Table 3 presents the six estimated models in terms of the marginal effects of the means. The first three models relate to eco-innovations with internal benefits and the second three model the external benefits. The different models include a fixed set of controls related to a firm's characteristics and vary in terms of the policy instrument used to address the expected differences caused by the government actions related to eco-innovative propensity.

As a consequence, the analysis of the results must be divided into two halves: Models 1, 2, and 3 consider the adoption of eco-innovations with internal benefits for each of the policy instruments appraised, whilst models 4, 5, and 6 consider the same framework for eco-innovation with external benefits. As the logistic regression produces coefficients not directly interpretable, it does not represent an accurate effect of the predictors on the dependent variable. As a consequence, the marginal effects of the means were estimated to quantify the change in the eco-innovative propensity, in percentage points, caused by a change in the exogenous variables.

Table 2. Descriptive statistics and correlations.

	Mean	S.D.	Min	Max	Kurtosis	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) ECO_internal_ben	0.62	0.485	0	1	−1.745	1									
(2) ECO_ext_ben	0.44	0.496	0	1	−1.936	0.546 **	1								
(3) Technological Regime	1.85	0.973	1	4	0.173	−0.029	−0.018	1							
(4) Size	1.45	0.613	1	3	−0.028	0.114 **	0.069 **	0.011	1						
(5) Human Cap	2.64	1.715	0	6	−0.754	−0.145 **	−0.108 **	0.319 **	0.095 **	1					
(6) Tech_innov	0.76	0.747	0	2	−1.116	0.107 **	0.152 **	0.168 **	0.082 **	0.126 **	1				
(7) Non_tech_innov	1.71	0.938	0	3	−1.015	0.235 **	0.221 **	0.031 *	0.068 **	0.116 **	0.274 **	1			
(8) Open_innovation	0.15	0.361	0	1	1.696	0.076 **	0.088 **	0.104 **	0.239 **	0.179 **	0.241 **	0.188 **	1		
(9) Envir_Regulations	2.03	1.002	0	3	−0.494	0.073 **	0.108 **	−0.029	0.130 **	−0.023	0.044 *	0.054 **	0.086 **	1	
(10) Envir_Taxes	1.59	1.047	0	3	−1.152	0.071 **	0.093 **	−0.072 **	0.054 **	−0.081 **	0.010	0.061 **	0.039 *	0.653 **	1
(11) Envir_Grants	0.93	1.021	0	3	−0.780	0.028	0.064 **	−0.027	0.072 **	0.009	0.031	0.045 *	0.077 **	0.323 **	0.409 **

**, significant at 0.01 (2 tailed).
*, significant at 0.05 (2 tailed).

Table 3. Model estimations (logit marginal effects of the means).

VARIABLES	ECO_Internal_Benefits			ECO_External_Benefits		
	(1)	(2)	(3)	(4)	(5)	(6)
tech_reg	−0.040	−0.037	−0.050	−0.023	−0.019	−0.024
	(0.093)	(0.092)	(0.092)	(0.046)	(0.046)	(0.046)
size	0.287 *	0.317 **	0.329 **	−0.089	−0.063	−0.060
	(0.153)	(0.152)	(0.152)	(0.068)	(0.067)	(0.067)
empud	−0.244 ***	−0.243 ***	−0.258 ***	−0.089 ***	−0.086 ***	−0.096 ***
	(0.055)	(0.055)	(0.055)	(0.028)	(0.028)	(0.028)
technological_innov	−0.255 **	−0.245 *	−0.246 **	0.266 ***	0.272 ***	0.270 ***
	(0.126)	(0.125)	(0.125)	(0.060)	(0.060)	(0.060)
non_tech_innov	0.447 ***	0.441 ***	0.452 ***	0.227 ***	0.224 ***	0.231 ***
	(0.097)	(0.097)	(0.097)	(0.048)	(0.048)	(0.047)
open_inno	−0.048	−0.025	−0.024	0.144	0.158	0.155
	(0.247)	(0.246)	(0.246)	(0.122)	(0.122)	(0.121)
ENEREG	**0.249 *****			**0.209 *****		
	(0.082)			**(0.041)**		
ENETX		**0.236 *****			**0.169 *****	
		(0.085)			**(0.040)**	
ENGRA			**0.105**			**0.125 *****
			(0.090)			**(0.041)**
Constant	2.235 ***	2.311 ***	2.588 ***	0.021	0.121	0.287 *
	(0.358)	(0.354)	(0.339)	(0.172)	(0.168)	(0.159)
Observations	2734	2734	2734	2734	2734	2734

Standard errors in parentheses.
***, $p < 0.01$; **, $p < 0.05$; and *, $p < 0.1$.

Model 1 and Model 2 test the effect of policy with-holders in the promotion of eco-innovations with internal benefits. The inclusion of these predictors aims to develop understanding on the role of environmental taxes, charges, or fees, which, based on [44,45,47,48], should have a positive effect in the adoption of ecological practices. In what concerns the regulations, the increase of its importance by the firm increases the probability of producing eco-innovations by 24.9 pp (percentage points). Taxes have a similar effect on its eco-innovation propensity (23.6 pp). It is confirmed that the use of tight measures to set the boundaries on environmental damage forces firms to adopt more efficient resource management actions. The present results are in agreement with previous models and are further reinforced by their prevalence in the different models run.

Benefiting from government grants, subsidies, or other financial incentives for environmental innovations is expected to increase the propensity to develop eco-innovations with both internal or external benefits [45,48]. For the present case, incentives were proxied by government grants and encompassed in Model 3; in this case, the policy incentive fails to reach significance, which means that the provision of public grants does not influence the propensity to perform eco-innovations with internal benefits.

The controls included in these models were partially significant: Concerning the technological regime, it is not significant in any of the models, which means that the adoption of eco-innovation practices is not constrained by the firm's technological regime. This result is, to some extent, surprising as there is a natural expectation that high-tech firms are more prone to adopt innovations with internal benefits. The same happens with open innovation strategies; accordingly, the combination of internal and external sources to innovate fails to influence the adoption of eco-innovations. In terms of the firm dimension, larger firms are more likely to adopt eco-innovations with internal benefits, reinforcing previous expectations.

Surprisingly, the adoption of eco-innovation practices is enhanced by non-technological innovations simultaneously performed; on the contrary, the existence of technological innovations decreases the probability of developing eco-innovative projects. Moreover, increasing the human capital intensity decreases the probability of performing eco-innovations, which is opposite to what was expected, as the endowments of skilled personnel should increase the involvement in and commitment to ecological initiatives and efficient resource management.

The similarities of the coefficients among the three models consolidate the robustness of the estimations, working as an endogenous robustness check, as controls do not vary in terms of the estimated signal and significance and vary very little in terms of magnitude. To avoid multicollinearity problems, the estimation of a policy package combining the three instruments was not considered; still, this also generates an insight for policy makers, proving, to some extent, the eventual redundancy of the simultaneous application of more than one instrument. It seems to be worth considering that subsidization by means of grants is ineffective in terms of eco-innovations with internal benefits, which should avoid a waste of public funds, as this instrument becomes accurate in the case of eco-innovations with external benefits.

Models 4, 5, and 6 present a similar framework to the former, notwithstanding the dependent variable, which is eco-innovations with external benefits. Similar results were achieved in terms of the controls, which means that the determinants of eco-innovation strategies are alike, regardless of the nature of the benefits achieved.

Table 4, below summarizes the hypotheses in test along with the proxies with which they were econometrically tested as well as their validation. In general the connections previously highlighted from the theory were further reinforced, with the exception of the importance of the technological regime and the open innovation practices. These results provide an additional emphasis to the upraising of new policy packages to encompass the singularities of each sector.

Table 4. Hypotheses in the test and their validation.

Hypotheses	Proxy	Validation
H1: Policy withholders such as taxes or regulations increase the adoption of eco-innovations	ENEREG and ENETX	Supported
H2: Policy enhancers such as grants increase the voluntary adoption of eco-innovations	ENGRA	Partially_sup
H3: Firms included in high-tech regimes are more likely to eco-innovate	TECH_REG	Unsupported
H4: A higher skill intensity leads to a higher probability of eco-innovating	EMPUD	Partially_sup
H5: Larger firms are more likely to adopt eco-innovations	SIZE	Supported
H6: Performing other types of innovations increases the likelihood of eco-innovation, but the effect varies, according to the nature of the innovation		
H6a: Non-technological innovations increase the likelihood of eco-innovation adoption	INNOV_NON_TECH	Supported
H6b: Technological innovations increase the likelihood of eco-innovation adoption	INNOV_TECH	Partially_sup
H7: Engagement in open innovation positively impacts the probability of eco-innovation	OPENINNOV	Unsupported

5. Discussion

During the last few decades, plenty of sustainability programs and initiatives have been set up to promote innovative actions. Policy responses and scientific research have been connected to appraise and improve the understanding of global environmental change and the connection to economic and social systems [25]. When examining the different policy instruments provided, important differences are found. In terms of *sticks*, once more, heavier environmental tax burdens or regulations will increase the propensity of developing eco-innovations with external benefits. Model 6 displays the importance of public grants in the development of eco-innovations with external benefits. Along the same line as previous literature, the most effective policy instrument is settling regulations, followed by levying environmental taxes. The failure of significance concerning the technological regime should be differently entangled as most of the policies, mainly those connected with funding, target these specific firm cohorts and it seems that the segmentation is not accurately grounded.

Regarding the importance of environmental taxes in the promotion of eco-innovation practices, policy makers should not feel tempted to indiscriminately raise their value, as there are other firm characteristics affecting the ecological likelihood, and such characteristics will make, on one hand, it easier for firms to support the tax burden, and on the other hand, it easier to adopt the desirable behavior.

The implementation of instruments with progressivity in value added and monitoring the results should perhaps be encompassed in future policy packages. Firms which innovate in non-technological domains are much more sensitive to the adoption of eco-innovation practices, which may allow the tax burden to be reduced as they already efficiently manage their endowments of resources.

As enrolment with different R&D sources by means of open innovation strategies is not significant, the inclusion of other players in the innovation ecosystem may enhance the results; sticking innovation networks to the attribution of grants should be taken into consideration, as it was expected that public support should be of a higher importance in the development of innovation activities. Given the importance of Open Innovation in the promotion of innovation ecosystems grounded in digital transformation [17], gathering the policy package to manage this source of knowledge properly deserves further attention.

In the same vein as Horbach et al. [47], who addressed the German and French case, in the Portuguese case, *sticks* seem to be more efficient as a public policy instrument, rather than carrots, in the promotion of smart resource management.

The empirical results reinforce extant literature on innovations with ecological aims [45,47–50]. First, it is evident that the adoption of these practices is connected to firms' structural characteristics, and, in the present case, the most important enhancer is the firm dimension and the withholder is the human capital. Open innovation strategies along with a technological regime do not influence these practices. As a consequence, policy makers should consolidate the effort to promote alliances in the development of innovative actions, and positively discriminate those involved. All in all, forcing involvement of the skilled labor force should be considered as they are more close to technology and technological literacy and should be the engines of innovation adoption inside organizations. Finally, the results indicate a higher impact of non-technological innovations over technological innovations on the probability of adopting eco-innovations. Once more, tax benefits should perhaps be linked to technological innovations to reinforce these practices.

According to the Portuguese CIS14, 36.8% of the respondents performed eco-innovations. Consequently stimulating these practices with a broader effect demands the exercise of reaching those not yet involved. It seems crucial that policy packages are provided with instruments highly impacting the development of ecologically-driven innovations [44] and exploiting their complementarities. Combined strategies, accordingly to external experience, work better than singular actions [14]. Defining firm clusters according to their characteristics and promoting micro-ecosystems would perhaps work better.

The poor results obtained concerning the open innovation strategy seem to show that firms are still tied to closed innovation frameworks. Policy makers must promote connections between the industry and the rest of the community, developing sustainable innovation ecosystems. Presently, the European Union is developing a common political effort to promote sustainability.

Open innovation 4.0 seems to be the turnkey for this target [17]. Co-creating innovative solutions encompassing environmentally responsible solutions with economic and social gains must be central to policy design. Moreover, there is a common belief that academia should play a central role in the exploitation of these complementarities, maximizing the spillover of these actions.

The results evidence that public funding only partially enhances eco-innovation adoption. Consequently, it seems more effective to design a smart taxation scheme rather than provide indiscriminate grants, which do not seem to be very valuable for firms. Of course, grants should be maintained to incentivize innovation activities, but the action cannot be plain. Along the same line as previous debates, there is a belief that combined actions would work better. In this vein, some fine tuning policy making will enhance the efficiency of resource management. Eco-innovation may work as a pre-requisite to enter government programs. Maintaining severe environmental policies in large firms, due to their larger concerns on cost savings, will result in a confirmed efficiency. This recommendation is reinforced by the empirical results and can be explained by the current tax progressivity. New policies to promote eco-innovations among SMEs should be traced, due to their representativeness in the entrepreneurial fabric. Finally, there is an urge to reinforce legislation and subsidization on specialized human capital resources devoted to its development. Given the centrality of achieving sustainability goals, in the promotion of economic prosperity encompassing social justice and respect for future generations, the adoption of policy actions is compelling. It is expected that these results will shed some light on the specific traits of the policy action, mainly in the context of small economies with a moderate innovative intensity.

6. Conclusions

The growing attention of consumers, firms, governments, and organizations on environmental issues raises the importance of conducting empirical studies to support and target appropriate policies. Therefore, this study, using the Portuguese CIS 14, explores the determinants of innovations with an ecological impact with internal and external benefits. Its adoption and the role of structural characteristics and different policy approaches were appraised through an empirical analysis, using a discrete choice model. The present policy proposals should encompass initiatives and investments to promote a green and digital transition; these aspects represent two closely linked priority areas, where investments are much needed. In the present context, there is great ecological pressure and this should be coordinated with social economic development. Green innovation has become the key symbol representing the core societal transition towards competitiveness and a sustainable competitive advantage.

Eco-innovation has been proven to be different from standard technological and non-technological innovations. Therefore, these innovations entail positive externalities, making their support crucial to achieving competitiveness and sustainability at one time, thus promoting smart growth. On the other hand, the externalities are embedded in the demand for public policy and regulations. The so-called ‘regulatory push-pull effect’ becomes central in the promotion of innovations with ecological benefits.

Policy actions implemented to stimulate these innovative strategies need to be carefully and individually designed. The present work casts light on the efficacy of the policy instruments, as well as the effect of the structural characteristics, in this vein; this appraisal is a crucial step toward improvement of the current and forthcoming policy mix.

Ecological innovations are central to responding to the devastation that the planet is suffering from. These actions are of particular importance in the EU, where important financial and institutional efforts are being developed. Recent literature argues that sharing and transferring knowledge is central in the promotion of eco-innovative behavior. The connection between open innovation and systematic eco-innovation is very strong; as a consequence, policy makers should encourage the development of sustainable innovation ecosystems.

Hopefully, managers and policy makers understand the importance of these co-creative innovation cycles in the promotion of efficient resource management and smart growth.

6.1. Theoretical Implications

The paper combines two mainstream perspectives on the sources of information for innovation; however, there seems to be loose links to the policy instruments. On the one hand, the empirical study proxies the policy with-holders and their importance in eco-innovation adoption. On the other hand, it approaches the enablers and their potential link to the innovation ecosystem. Each of the explanatory variables encompasses different firm characteristics influencing the innovative performance, in general, and eco-innovation, in particular.

Important conclusions can be drawn with respect to the firms' characteristics that leverage eco-innovative activities. A major focus should be placed on the importance of increasing the capacity to absorb external knowledge from the ecosystem for the purpose of ecological innovations. Worldwide market pressures, along with the planet emergency, are forcing a persistence in eco-innovative attitudes. As a consequence, classical innovations are arguably as urgent as eco-innovations, but, to some extent, they may go along together. The contributions of technological and non-technological innovations to eco-innovations are of great importance and require further reinforcement. Learning processes do matter; however, human capital availability seems to discourage eco-innovations, which needs to be fully understood.

The design of an effective policy mix requires a careful consideration of the context and circumstances in which financial support is given to produce an effective benefit. Perhaps this instrument demands being encompassed with other vectors of the firm's economic activities. Certainly, the role of eco-innovation grants requires a deeper investigation as subsidization is expected to leverage innovative strategies.

6.2. Practical Implications

This first set of results encompassing policy instruments and firm characteristics has important implications for the design of smart policy mixes supporting eco-innovations. These actions should support not only internal eco-innovative efforts, but also interactions with external players and knowledge sources in the innovation ecosystem. Findings prove that firm characteristics affect the likelihood of adopting eco-innovations. As a consequence, the managerial strategies have to address a firm's singularities and behave parsimoniously when choosing strategies and partners inside the innovation ecosystem.

Considering this, network policies and knowledge co-creation initiatives may play an important role as they involve the community pushing the firms to become environmentally sustainable. These policy actions are specific to the ecosystems in which firms are embedded, as well as the feasibility of the implementation of open innovation frameworks. Positive effects are expected when firms are able to disentangle knowledge spillovers arising from the ecosystem and do not collapse with excessive information, which, in most cases, is incomprehensible. In a nutshell, knowledge sourcing should not be a one-fits-all strategy in the environmental area.

Eco-innovations have been proven to be a complex organizational challenge, while mandatory for survival in increasingly conscious markets. Firms must harmonize a set of knowledge emerging from different sources in variety of ecological solutions. Organizational competences are therefore essential for this process to succeed. Supporting this process should be considered a further aspect in the design of smart policy mixes promoting the adoption of environmental innovations. As previously mentioned, policy-makers should be very cautious when trying to amplify the external benefits of eco-innovation through open innovation frameworks. Communication channels are very unique and organizations need to have technological and cultural proximity. Therefore, they will depend on the targeted cluster. A further step towards policy stringency relies on the identification of beneficial interactions with the various players according to the identified targets.

6.3. Limitations and Future Lines of Research

The study is based on a cross sectional analysis, encompassing the 2012–2014 time frame. It covers a broad sample of 7083 firms; however, it is related to a particular country—Portugal. The CIS database is useful for grasping information on a large number of observations, yet it has some limitations. It is not purposefully made to evaluate eco-innovations and thus lacks some details that could be of further use for finer analysis. The present analysis covers one specific country, so may not be able to draw general conclusions. As a consequence, the present results could be further reinforced through expansion to other countries, as the CIS, allowing for a comparison of European countries. To address some of the limitations of this study, future research could add additional spells of the CIS to develop a broader database. Currently, enlargement of the time span is not possible, as these questions are only present in the CIS14 edition. Future research should encompass panel data analysis of different countries. This analysis would allow the comparison of how effective the different policies were in each ecosystem. All in all, appraising policy effects over time and possible adjustments will generate a clearer picture.

This period has some singularities, as Portugal was immersed in the economic crisis that took place worldwide in 2008 and it may draw a pessimistic scenario. However, given the present economic context, and the negative expectations of the macroeconomic context transversely affecting the world, it seems an accurate forecast. These results can help policymakers to take action in the near future, so that they can learn from the eco-innovation determinants of the past and avoid policy inefficiencies in the near future.

6.4. Policy Recommendations

The present research contributes to the debate on the role of the effectiveness of the different policy instruments in the promotion of innovative activities with environmental benefits. It combines two perspectives: The *sticks* and *carrots*. Given the transversal importance of public funding, there is a strong recommendation to maintain the conventional policy instruments, such as funding. Despite some beliefs that the ultimate innovation ecosystems would be self-sustained and, being dynamos of the innovation cycles, there is still room for financial boosters which will reduce the burden of innovation costs. Narrower strategies of collaboration or strategic alliances according to the innovation purpose seem to be more effective than general connections. The proposed policy mix, despite being flexible, needs to be based on general empirical findings, such as the common subsidization of high-tech regimes to complement their traditional technological innovation with ecological and the disregarded low tech sectors; the promotion of persistent engagement on different innovation types, especially technological innovations, through severe *stick* policies; continuing to promote R&D, through subsidization in other innovation types; developing awards and positive distinctions to promote a firm's visibility; and promoting eco-innovations through open innovation by shortening the pathway between academia and firms. Sharing knowledge is useful for the acceleration of growth and the cost reduction of innovation processes; however, chirurgic knowledge searches near the correct sources will increase the efficiency level of the firms. Grasping the optimal combination for each purpose among the globalized knowledge networks suggests the co-existence of infinite possibilities. Keeping in mind the importance of innovation in the promotion of competitiveness, along with the emergency of resource preservation, adopting ecologically-driven innovations appears to be a natural option in the promotion of sustainable development. Designing this multidimensional policy framework to enroll all players and fully exploiting the potential of the innovation ecosystem will determine the success from both a micro- and macroeconomic perspective, leading to a sustainable and prosperous future for all.

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