Industry and Innovation

ISSN: 1366-2716 (Print) 1469-8390 (Online) Journal homepage: http://www.tandfonline.com/loi/ciai20

Design and eco-innovation: micro-evidence from the Eurobarometer survey

Claudia Ghisetti & Sandro Montresor

To cite this article: Claudia Ghisetti & Sandro Montresor (2018): Design and eco-innovation: micro-evidence from the Eurobarometer survey, Industry and Innovation, DOI: 10.1080/13662716.2018.1549475

To link to this article: https://doi.org/10.1080/13662716.2018.1549475

Published online: 26 Nov 2018.

INDUSTRY AND INNOVATION
https://doi.org/10.1080/13662716.2018.1549475

Routledge
Taylor & Francis Group

ARTICLE

OPEN ACCESS Check for updates

Design and eco-innovation: micro-evidence from the Eurobarometer survey

Claudia Ghisetti[a,b] and Sandro Montresor[c]

[a]DG Joint Research Centre, European Commission, Ispra, VA, Italy; [b]Department of Economic Policy, Catholic University of Milan, Milan, MI, USA; [c]Faculty of Economics and Law, Kore University of Enna, Enna, EN, Italy

ABSTRACT
This paper investigates the role of design in making firms eco-innovate. Going beyond the 'packed' approach of environmental studies about 'eco-design', we maintain that the eco-innovative impact of design is correlated with the firm's decision to invest in it. In turn, design investment is assumed connected with the use firms make of design. By pooling the Eurobarometer 2015 and 2016 surveys, we test for these arguments with respect to a sample of nearly 4500 European and non-European (US and Switzerland) manufacturing firms. Results confirm that the firms' capacity of eco-innovating increases when they invest in design, also by making this investment dependent on the role of design within the firm. The relationship between eco-innovation and design appears robust with respect to the different kinds of 'eco-innovators' that the Eurobarometer enables us to consider, while some interesting variability emerges when splitting the sample by group of countries and industries.

KEY WORDS
Eco-design; eco-innovation; design

JEL CLASSIFICATION
Q55; O31; O32

1. Introduction

The role of design in determining the environmental impact of new products and production processes has been long since recognised. In the literature on new product development, 'approximately 80% of a product's environmental profile' has been claimed to be 'fixed under the phase of design and concept creation' (McAloone and Bey 2009, 5). Indeed, design can be used by firms as an environmental leverage in different ways, like in using materials/energy more efficiently and responsibly, planning the product life-cycle to extend its duration, encouraging its environment-friendly use, and managing its end-disposal.

The environmental impact of design has found its first conceptualisation in the '90s with the notion of 'eco-design' (for an historical review of the concept, see Ryan (2003)). In environmental economics, the concept rapidly enriched with a number of specifications[1] and soon became the cornerstone of environmentally sustainable

CONTACT Claudia Ghisetti claudia.ghisetti@ec.europa.eu; claudia.ghisetti@unicatt.it

This article has been republished with minor changes. These changes do not impact the academic content of the article.

[1]Among the others, design-for-the-environment (DfE), environmental-design, environmentally-sustainable-design, environmentally-conscious-design, life-cycle design (see Carrillo, Del Río González, and Könnölä 2009).

business practices (e.g. Life Cycle Assessment (LCA) and Product-Service Systems (PSS)) and policy actions (e.g. the Eco-design Directive and the Energy Labelling Directive in Europe) (Tukker et al. 2001). In the latest years, eco-design has become one of the pillars of the 'Circular Economy' paradigm and of the recent action plans for its development in Europe (EC 2015; European Environmental Bureau 2015; Ellen Macarthur Foundation 2015).

The rationale of these policy interventions is helping firms internalise the eco-externalities of design, by making them incorporate environmental factors into new product development practices. In so doing, it is somehow taken for granted that design will have an environmental impact for the simple fact of this 'integrative' use, being ready-available in the firm's environmental tool-box.

In our view, this 'eco-design centric' way of looking at and promoting the environmental impact of design is simplistic and 'packed' in different respects. First of all, it disregards that an environmental use of design requires firms to invest resources in its development and to conceive it as a strategic intangible asset for the sake of eco-innovation. Second, the standard eco-design approach also neglects the role/use design has in the business model through which firms (eco-)innovate. For example, it does not retain that making a simple aesthetic (or occasional) use of design might provide firms with lower incentives to invest in it and thus make them less capable to get an eco-impact from design. Third, the same approach downplays a wide set of structural characteristics (e.g. size, age, internationalisation, …) that could drive the firm's decision to invest in design and to grasp its environmental benefits by eco-innovating. Still as an example, it is not considered that young firms could have more degrees of freedom in making a novel, environmental use of design than older, incumbent ones.

All of the previous aspects suggest that the eco-impact of design needs to be 'un-packed', in order to devise more effective strategic and policy actions to foster it. In concrete terms, this entails addressing a different research question than 'how design can be used environmentally'. It should be rather investigated whether design, *per se*, can actually be a driver of innovations with a favourable environmental impact.

This is the aim of this paper, which investigates the role of design as an intangible asset in driving the firms' opportunities and capacities of eco-innovating. More precisely, it focuses on design investments and, by controlling for their determinants, it looks at their effect on the firm's propensity to adopt environmentally sustainable technologies.

From a theoretical point of view, we go beyond the 'black-boxed' way the relationship at stake has been so far investigated in environmental eco-design studies. We actually integrate this approach with a recent stream of research on the management of design and intangibles for the sake of innovation (Montresor and Vezzani 2016; 2017) and eco-innovation at the firm level (Boks 2006)

'Un-packing' the eco-impact of design does also require a novel empirical strategy. As such an impact needs to be ascertained, rather than assumed, systematic evidence on both environmental performances and design practices at the firm level is needed, in order to integrate the typical case-study approach of the extant literature on eco-design. For this reason, we base our analysis on the pool of the 2015 and the 2016 Eurobarometer surveys, from which we observe design and eco-innovation for about

4500 manufacturing firms in 28EU countries (plus US and Switzerland) over the period 2012–2015.[2] With respect to these firms, we estimate standard and bivariate recursive probit models, in which the propensity to adopt new sustainable technologies depends on their investments in design, and in which these investments are in turn affected by some consistent design drivers and a set of proper controls.

Results confirm that the firms' capacity of eco-innovating increases when they invest in design, also by making this investment dependent on the role design within the firm. The relationship between eco-innovation and design appears robust with respect to the different kinds of 'eco-innovators' that the Eurobarometer enables us to consider. On the other hand, some interesting variability emerges when we split the sample between different groups of countries (EU15 vs. non-EU15) and of industries (low, medium-low, medium-high, and high-tech).

The rest of the paper is structured as follows. Section 2 positions our analysis in the extant literature. Section 3 presents the dataset and the econometric strategy of the empirical application. Section 4 illustrates its results and Section 5 concludes.

2. Background literature

The scientific debate on the eco-impact of design is nowadays very intense. In environmental economics, such an impact has been mainly investigated by research on 'eco-design'. This can be broadly meant as the 'integration' intro product-development of an additional environmental dimension, whose specification has evolved over time: from the initial reduction (increase) of environmental overloading (efficiency), passing through the later implementation of a green image and brand name, up to the recent realisation of the circular economy (Karlsson and Luttropp 2006, Braungart, McDonough, and Bollinger 2007).

Most of eco-design studies to date are based on coupling design/engineering principles with environmental sciences and have so far resulted in a massive technical literature, which has identified a wide set of eco-design meta-approaches (e.g. Yang and Chen 2011), development systems (e.g. van Nes and Cramer 2006; Hänsch Beuren, Gitirana Gomes Ferreira, and Cauchick Miguel 2013), and implementation techniques and tools (Knight and Jenkins 2009; Vallet et al. 2013).

The results obtained about the effectiveness and efficiency of these practices are of extreme importance and have made of eco-design the dominant approach to the environmental impact of design.[3] On the other hand, while for sure important, in our opinion such an approach is a 'packed' and somehow 'black-boxed' way of looking at the same impact, mainly for two reasons. First of all, in this stream of studies design is assumed to be the 'door' through which environmental issues simply enter into

[2]We thank an anonymous reviewer for suggesting us to combine the two sources, rather than using one wave of the Eurobarometer only. Unfortunately, the lack of a unique identifier for the respondent firms and the specific sampling structure of the survey do not allow us to construct a proper panel with which to investigate the eco-impact of design in a longitudinal manner. The analysis is thus performed on a pooled, cross-sectional sample of firms, with the implications we will discuss in the empirical section of the paper.

[3]In particular, the environmental impact of eco-design practices has been shown to depend on the actual timing of their implementation during the product-life-cycle (e.g. Luttropp and Lagerstedt 2006) and on the specific kind of products to which they are applied (e.g. Vezzoli and Sciama 2006). Furthermore, a series of trade-offs have been identified with respect to their combined implementation (see Byggeth and Hochschorner 2006).

product development. Rather than on the design capacity of being actually eco, the focus is rather on the 'keys' to open such a door and make the integration happen. Second, eco-design studies are generally qualitative analyses, based on case-studies (e.g. Cerdan et al. 2009), or quantitative investigations, but conducted on limited samples of firms (e.g. Santolaria et al. 2011), which make their extension and generalisation hard to make.

Some of the latest literature on eco-design has tried to extend this packed perspective by linking it to the notion of 'eco-innovation' (EI), meant as 'the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to [firms] and which results, through-out its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives' (Kemp and Pearson 2007, p. 10). Quite interestingly, these studies have shown that industrial firms 'perceive' their eco-design practices as (integral part of their) EI projects, and that the former are even deemed to collapse into the latter depending on the meaning of the two focal concepts, and on the nature of the interviewed firms: for example, innovation-driven companies (Santolaria et al. 2011), rather than eco-innovative SMEs (Bocken et al. 2014), or companies already engaged in eco-design approaches (Cluzel et al. 2014). On the other hand, the focus of these studies continues to be on 'exogenous' practices of eco-design, without considering the way design is and should be treated within the firm, in terms of resources and management practices, in order to yield an eco-innovative outcome. Furthermore, the studies at stake are still based on limited industrial surveys and thus have a limited result generalisability.

In order to move further towards a more unpacked kind of analysis, in this paper we still refer to firms' EI. However, we look at design in broader and more generic terms, rather than as an already eco-directed set of practices. In so doing, we contribute to the academic debate on the drivers of EI, in which design has been only limitedly investigated in such a role. Indeed, few underlying mechanisms of the relationship at stake have been singled out so far. Following the 'regulatory push-pull effect' to EI (Horbach, Rammer, and Rennings 2012), a first mechanism has been identified in the policy enforcement of design as a driver of EI, by recommending its eco-use through dedicated environmental directives (e.g. eco-labelling and energy-labelling) (Ghisetti and Pontoni 2015; Triguero, Moreno-Mondéjar, and Davia 2013).[4] An additional mechanism has been identified by the literature about skills and technologies, in which design (along with engineering) has emerged as an important competence for mastering green technologies (Vona et al. 2015): a result confirmed by firm-level patent analyses, showing that green innovators are firms operating in design-intensive activities (e.g. Noailly and Smeets 2015). Still though the use of patents, design has been suggested to be a strategic instrument to increase product complexity and thus the appropriability of the EI returns (Horbach, Oltra, and Belin 2013). Last, but not least, design activities, along with other non-R&D based ones, have been found to be a significant source of knowledge for an 'informal' mode of eco-innovating – which is based

[4]In this last respect, a broad research stream has exploited patent data and tested for the role of environmental regulation stringency (e.g. Albrizio et al. 2017), energy prices (e.g. Popp 2002; Noailly and Smeets 2015) and multiple policy instruments (e.g. Johnstone, Haščič, and Popp 2010; Popp 2006) in the introduction or diffusion of environmental technologies.

on Doing, Using, and Interacting – rather than on Science, Technology, and Innovation (Marzucchi and Montresor 2017).

As a way to contribute to this latter stream of literature, in this paper we claim that, consistently with the analysis of intangibles and innovation (see Montresor and Vezzani 2016; Ciriaci 2017), design should be conceived as an intangible asset, which needs to be built up and managed appropriately in order to increase environmental sustainability. Once conceived in these terms, that design positively contributes to EI can't be taken for granted, and rather needs to be argued and proved. Firms' resources are actually limited by definition and their design destination could represent an opportunity costs of possibly more eco-innovative investments, such as in R&D or in the training of green skills. Similarly, shaping the business model in such a way to plug design centrally in it, could make the firm divert from other less or no-design centric, sustainable business models.

Both of these counter-arguments can be opposed by looking more carefully at the business dimension of design. In so doing, we draw on and extend another field of studies, which has looked at the organisational pre-conditions for the integration of environmental aspects into new product development (e.g. Boks 2006). Combing this literature with that on intangibles and innovation, we expect that design investments and the design position in the firm's business model are two drivers of EI, which operate systematically across firms of different structural (e.g. age and size) and contextual (e.g. sector and country) characteristics. Far from representing the equivalent of the eco-design/eco-innovation link we have pointed out above, these two drivers add to the analysis of 'hard' design aspects (i.e. eco-design practices) that of the 'soft-side of design' (Boks 2006) and point to a variety of business-related aspects, which are responsible for an innovative and sustainable impact of design.

First of all, design can have such a 'soft' role when firms invest resources in its development. In general terms, by allocating time and money to design projects, firms formally commit to increase and improve the understanding of their products' functionalities/aesthetics and of the basic operations of their production processes. In this way, they can augment their creativity in both respects, attain higher capacities of coupling their technology with the customer needs, and increase their innovation propensity (Tether 2006). Systematic evidence of the impact of design investments has been found only on 'standard' innovations so far (Galindo-Rueda and Millot 2015; Montresor and Vezzani 2016, 2017). However, we can expect to find a similar effect also on the firm's propensity to EI. Through design investments, even when they are not explicitly targeted to the development/adoption of formal eco-design practices, firms could discover new technological opportunities and solutions with a favourable environmental impact. Of course, should the design investment be directed to the implementation of eco-design techniques, the impact could be expectedly greater and/or more immediate. However, design (investments) could work in an eco-manner also by stimulating firms to develop a creative thinking towards 'naturally enterprising' and 'greening of business products' (Beard and Hartmann 1997), as well as to favour a 'transition management' towards sustainable innovations (Mulder 2007).

A second 'soft' kind of aspect of design to which the literature has paid attention is the position of design within the firm. Linking design with environmental abilities actually requires the firm to set the former at the centre of both multi-disciplinary teams and external partnerships for the realisation of EI (Carrillo, Del Río González, and Könnölä 2009; Braungart, McDonough, and Bollinger 2007). As revealed by a number of case-studies, successful eco-design projects usually rely on the constitution of dedicated organisational platforms, which are placed at the core of the firm's business model (Johansson and Magnusson 2006; Tingström, Swanström, and Karlsson 2006). More in general, the transition towards such a 'sustainability-driven business model', based also and above all on EI, entails that design and designers keep a pivotal role in setting the firm's strategy and priorities (Esslinger 2011). This is also what emerges from the analysis of the effectiveness of Product Service Systems (PSS), meant as business models to reduce consumption and increase sustainability by altering how products are delivered and used by providing services (like in the case of care-sharing) (Mont 2002; Tukker and Tischner 2006; Hänsch Beuren, Gitirana Gomes Ferreira, and Cauchick Miguel 2013). Indeed, in all of the specific variants in which products and services can be combined (Tukker 2004), the environmental impact of PSS depends also and above all on 'product and service design tatics', through which the entire life-cycle of the product is considered to reach an 'adapted product and service design' by working on functionality and customization (Reim, Parida, and Ortqvist 2015, p.71).

Drawing on the previous arguments, and combining them with the EI literature, we expect that the firm's propensity to eco-innovate increases by increasing the 'complexity' of the use of design within it, and with the 'centrality' design is accordingly given in the firm's business model (Montresor and Vezzani 2017). To be sure, the use of design within the firm could also affect the extent at which firms decide to invest in its development. For example, in case design is mainly used by the firm for enhancing the appearance and attractiveness of the final product, its propensity to invest in design would be lower than when design is an integral component of the company's strategy. Accordingly, the position of design within the firm and its design investments represent two crucial factors of the eco-impact of design on which more attention is required. As we already said, the same impact is also in need of a more systematic empirical analysis than that carried out so far. To such a need we aim at contributing with the empirical application presented in the following section.

3. Empirical application

3.1. Data

Our empirical analysis refers to a sample of about 4500 European and non-European (US and Switzerland) manufacturing firms, obtained by pooling two recent Eurobarometer surveys: the Flash Eurobarometer-415 on 'The Innovation Trends at EU Enterprises' (in brief, the Innobarometer 2015), and the Flash Eurobarometer-433 on "EU business innovation trends (Innobarometer 2016).[5] These are two subsequent releases of the same questionnaire (available from the relative summary reports at http://ec.europa.eu/growth/industry/innovation/facts-figures/innobarometer/), submitted to two anonymous and thus unmergeable samples of firms at the beginning of 2015 – asking questions since the year 2012 – and at the beginning of 2016 – since

[5]The survey does also cover a number of non-manufacturing and services industries, which we have however excluded as one of our focal variables (on eco-innovations) has been posed only to manufacturing ones.

the year 2013 – respectively. In the absence of unique firm identifiers, a proper panel can't be built up and the relative observations can thus only be generically and cross-sectionally referred to the period 2012–2015.

Unlike previous topic-specific Innobarometers, the two at stake are more general and contain firm-specific information on a wide variety of aspects, such as: different typologies of innovation, including eco-innovations; innovation drivers, obstacles and performances; tangible and intangibles investments; specific highlights on both policy and company features, among which, those of interest for our study, that is, design investments and the use of design within the firm.

As we will see in the following Section, in order to avoid systematic response-biases (see Montresor, Perani, and Vezzani 2014), the majority of the survey questions are of qualitative nature and consist of dichotomic or at most categorical information. For the same reason, unlike the Community Innovation Survey (CIS), the Innobarometer uses an open approach to definitions and concepts, leaving the respondent free to interpret their meaning, though at the inevitable price of a lower accuracy. In particular, the Innobarometers at stake try to infer the presence of eco-innovations by surveying the firms' adoption and plans of adoption (in the following year) of generically termed 'sustainable manufacturing technologies', with respect to which the following succinct definition is provided: 'i.e. technologies which use energy and materials more efficiently and drastically reduce emissions' (Question Q11A). Sticking to the principles of innovation economics, the adoption of technologies is of course different from their introduction, both in terms of drivers and effects: strictly speaking, the former actually pertains to the stage of innovation diffusion rather than creation/invention, as for the latter. On the other hand, with respect to EI, the same distinction is harder to draw and thus unfrequently made in survey-based empirical studies. In the extant literature, the focal aspect is actually the innovative environmental profile that firms take on, through their products and/or processes, even if these occur through the adoption of technologies, which are already available out of their boundaries ('new to the firm' only). This is also the case of the Innobarometers we use, which do not have other questions on the actual introduction of sustainable technologies. Conversely, relevant information for the sake of the EI introduction should/could be obtained through patent data, which would however limit the opportunities of investing the nuances of the role of design offered by survey data.[6]

In the same survey, design investments are captured through a 'categorical' question on tangible and intangible investments, taken and adapted from the previous Innobarometer 2013, in turn inspired by the NESTA intangible survey for the UK (see Montresor and Vezzani 2016). With respect to the use of design, the relative question has been built up by drawing on the 'ladder model' and ordering the use of design hierarchically, from its absence to more integrated and sophisticated uses within the firm (see Galindo-Rueda and Millot 2015, p. 27). In this case too, an open approach to the survey-question is adopted and respondents are provided with no design definitions and/or examples: this is particularly the case of the 'steps' of the design-ladder, which are synthetically and generically presented in the way we will say in the following. Last but not least, the questions on the firm's innovation outcomes and on its innovation-related performance are taken and adapted from the CIS.

[6]Needless to say, the absence of firm identifiers also prevents us from looking at the green patents of our sample firms.

In spite of its richness, the nature of the Innobarometer survey does require caution in the empirical analysis. In addition to the response biases it could suffer from, being a 'flash' kind of survey (i.e. administered only via CATI), it is a cross-sectional one (also in our pooled version), like other surveys on innovation (e.g. the CIS), which are however largely used in the relative econometric literature (Mairesse and Mohnen 2010). As we already said, an alternative solid strand of literature exists that uses patents as a proxy of EI also in a longitudinal manner (e.g. Popp 2002), thus allowing for a more proper investigation of causality. However, this would not allow us to obtain information on firm's design investments and strategies for our research questions. Furthermore, as we also said, the focus of our study is not on the generation of environmental technologies, but on their adoption, with respect to which survey data are more suitable than patent ones.

3.2. Variables

Our focal *dependent variable* is the firm's adoption of eco-innovations, *EI*. This is proxied by a dummy, which takes value 1 if the firm has already adopted and/or plans do adopt sustainable manufacturing technologies in the very next future (next year), and 0 otherwise.[7]

As far as the *explanatory variables* are concerned, we draw on the extant literature about EI drivers, based on the interplay between regulations, demand, technological conditions, and firm-specific factors (see Horbach, Rammer, and Rennings 2012; Rennings 2000; Horbach 2008). Admittedly, such an approach does not have an exhaustive coverage of drivers, especially with respect to the inclusion of strategic and managerial aspects at the company level (see Del Río, Peñasco, and Romero-Jordán 2016). However, we deem that proxying for each and every of the different domains of the regulatory push-pull approach, and including standard dummies for context-specific effects (e.g. country and sector), should be preferable to overfitting the model for the EI determinants with other variables not related to the same approach. To be sure, the data available from the Innobarometer does not allow us to make much more with respect to these 'extra' variables. In particular, we miss information to control for cost savings and/or past innovation activities, to mention a few.

We first try to account for the adoption of EI with a variable capturing the presence of environmental regulations. Unfortunately, as is usually the case at the micro-level, such an information is missing from the Innobarometer. As a second-best, we have thus referred to the Eurostat database and considered, at a more aggregated level, the variable *ENVREGL*, defined as the expenditure on environmental protection by country-sector in the survey period. Given that this regulation variable is based on expenditures, it may suffer from endogeneity (see Brunel and Levinson 2016). Because of this limitation, given that it is not a core variable of our model, we have chosen to plug *ENVREGL* only in its benchmark specification (see below) and to test for the robustness of our results to its exclusion.[8]

[7]As the simultaneous consideration of past and future innovation could lead to spurious results about their drivers (see Ziegler 2013), we tested for the robustness of our results by considering adopted sustainable technologies only. Results have been found to be consistent with those reported in the main text, and are available from the authors upon request.

[8]Results, available upon request, are robust to the exclusion of *ENVREGL*. Results are also robust to the inclusion of the full set of country-sector interactions, which would capture country-sector variability of environmental regulations, as reported in the tables of results (e.g. Column 8 in Table 3 or Column 3 in Table 5). It should be noticed that, although more exogenous proxies exist in this domain (like the Environmental Policy Stringency indicator (EPS) by the OECD), these are only available at the country-level (Botta and Kozluk 2014, Albrizio et al. 2017; Mazzanti et al. 2016) and would have thus entailed a loss of country-sector variability.

We then proxy for the firms' capabilities of eco-innovating in different respects. To start with, we look at whether firms have an 'R&D status', of whatever intensity, by building up a dummy, *RD*, which takes value 1 if firms have a positive share of turnover invested in such an activity, and 0 otherwise.[9] In order to distinguish the status of higher vs. lower innovation investor, we have instead built up another dummy, *HIGHINNO*, taking value 1 if the firm invested in innovation activities more than 11% of its turnover.[10]

The set of EI micro-regressors is completed by some structural features of the sample firms, usually referred in the literature as 'firm specific factors', such as: their size, proxied by the Log of the number of their employees, *LSIZE*; their age, proxied by their being young (i.e. founded after January 2014 or 2015, depending on the relevant wave) through a dummy, *YOUNG*; their belonging to a group, still with a dummy, *GROUP*; and their degree of internationalisation, as revealed by the percentage of their turnover from sales in EU or other countries out of their own, *INTERNATIONAL_sales*. In particular, this last question enables us to control indirectly for the role of 'demand conditions' in driving EI.

Our research hypotheses about the role of design for EI (see Section 2) are tested by augmenting the previous array of drivers in two respects. On the one side, we consider whether firms have an economically significant engagement in design by building up a dummy, *DESIGN_inv*, taking value 1 if they invest in design an appreciable share of their turnover, that is, more than 1% of it.[11] On the other side, we refer to the use of design within the firm by exploiting the 'ladder model' adopted by the Innobarometer. Following this model, firms have been asked to 'describe the business activities with regards to design', apart from the benchmark one ('Design is not used in the firm, it is not relevant', *DESIGN_NOT_USED*). These categories/dummies range from a 'non-systematic' use of design (*DESIGN_NOT_SYST*), to a merely 'aesthetic' function (*DESIGN_AESTHETIC*), an 'integral' recognition of its manifold functionalities (*DESIGN_INTEGRAL*), up to a 'central' role for the firm's business activities (*DESIGN_CENTRAL*). Of course, these items have a very limited informative value of the extent at which design is actually embedded in the firm's business model. On the other hand, the same categories are at least indicative of how design is treated within the firm, possibly in connection to its business model.

Once introduced the previous design-related variables, whenever the econometric model permits it (see the result section), a final augmentation of the model will be

[9]Although R&D expenditure is available for progressively higher domains of its turnover share, in our benchmark estimates we opted for a parsimonious specification, which simply controls for the presence of an 'R&D status' by dichotomising it with respect to 0. Quite interestingly, when the different categories of R&D investments on turnover are plugged in the estimates, by using as a benchmark the category of 0%, the higher the category, the more significant and higher its marginal effect on EI. Results are available from the authors upon request.

[10]Given that the choice of 11% as percentage of turnover invested in innovation is inevitably arbitrary, we have tested whether results change by using the closest lower percentage made available in the same question of the survey, that is, 6%. Results are available from the authors upon request and are robust to this alternative threshold too.

[11]Although design investments are also available for progressively higher domains of turnover shares, the dichotomisation of our focal variable is here imposed by the need of dealing with its possible endogeneity in the estimates, although at the price of a less rich specification of it (see the econometric strategy). It should be noticed that, when the different categories of design investments are plugged in the estimates with respect to the benchmark of 0%, they are all significant but their magnitude is pretty similar. This suggests that, for the sake of EI, it is the choice of investing or not in design that matters, rather than its size, thus supporting our dichotomisation choice. On the other hand, as Table A1 (probit) and Table A2 (bivariate probit) in the Appendix show, results do not change by setting *DESIGN_inv* equal to 1 in case of any positive share of design investment upon turnover (i.e. *DESIGN_inv* > 0%).

obtained by looking at the role that firm size and age could have in moderating the impact of design investments on EI, with different possible outcomes. Drawing on some recent research (see Leoncini et al. 2017; Marzucchi and Montresor 2017), we actually expect that being large rather than small could entail different problems in the firms' exploitation of their intangibles for getting green: for example, administrative/organizational complexity (disfavouring large firms) vs. too low scale of design use (disfavouring small firms). Similarly, we can expect that being young (old) could allow firms more degrees of freedom (experience) for integrating environmental considerations in design. Accordingly, the model is augmented by two interaction terms, between *DESIGN_inv*, and *LSIZE* and *YOUNG*, respectively. These variables are intended to capture whether the eco-impact of design is positively or negatively moderated by them.

Table 1 provides a synthetic illustration of the definition and descriptive statistics of the relevant variables

3.3. Econometric strategy

In a baseline specification we first estimate an EI-adapted knowledge production function, augmented by the role of design. In particular, given the dichotomic nature of our y_1 dependent variable, *EI*, we estimate the following probit model:

$$P(y_1 = 1|D, X, Z) = \Phi(\mathrm{D}'\beta_1 + \mathrm{X}'\beta_2 + \mathrm{Z}'\gamma) \tag{1}$$

In Equation (1), Φ is a standard cumulative normal function, D the vector of our five design related variables, in terms of investments and position within the firm, X and Z the (other) EI determinants and firm-specific controls we have been able to capture. Country and sector dummies are also included.

At the outset, the estimation of (1) can provide us with some useful insights on our research questions. In the same respect, Table 2 shows that collinearity is not an issue in doing that. The variance inflation factor, computed to spot the presence of multicollinearity in the covariates, is close to the lower bound of 1 for most of the variables and it is always lower than 1.5. An exception is that of country and sector dummies, which have higher values but always lower than 2.5. Overall, the mean VIF is 1.75. This supports the absence of multicollinearity issues in our models.

A more accurate and efficient estimation of the eco-innovative impact of design requires us to consider the possible endogeneity of the firm's decision to invest in it. In particular, a problem of reverse causality could be latent, as design investments might be spurred by the adoption of EI, rather than the other way around. In order to tackle this issue, we thus estimate a recursive bivariate probit (Greene 2008, Maddala 1983). In particular, we separate our two sets of design-related variables in light of their different nature, and tries to make design investments exogenous before looking at their impact on EI.

As discussed by Greene (2008), the class of bivariate probit models is a natural extension of the probit ones, which allows for two equations having correlated disturbances. In our case, the model adopted is a specific case of bivariate probit, with recursive equations. This is due to the fact that *DESIGN_inv* is, on the one hand, among the determinants of the outcome variable of interest (*EI*); on the other hand, the

Table 1. Main variables: definition and descriptive statistics.

	Variable	Description	N	Mean	SD	Min	Max
1	EI	D equals one if the company has adopted or plans to adopt in the next year sustainable manufacturing technologies	4465	0.42	0.49	0	1
2	DESIGN_inv	D equals one if Design of products and services has a positive share (> 0%) of company' turnover investments	4465	0.53	0.50	0	1
3	DESIGN_NOT_USED	D equals one if design is not used in the company	4465	0.23	0.42	0	1
4	DESIGN_NOT_SYST	D equals one when the company does not work systematically on design	4465	0.16	0.36	0	1
5	DESIGN_AESTHETIC	D equals one when design is used as last finish to enhance appearance and attractiveness of the final product	4465	0.17	0.37	0	1
6	DESIGN_INTEGRAL	D equals one when design is an integral component in the company's strategy	4465	0.27	0.45	0	1
7	DESIGN_CENTRAL	D equals one when design is a central element in the company's strategy	4465	0.18	0.38	0	1
8	RD	D equals one if R&D has a positive share (> 0%) of company' turnover investments	4465	0.62	0.49	0	1
9	LSIZE	Log in the number of employees	4465	3.58	1.67	0	9.16
10	YOUNG	D equals one if the company is young, i.e. if it was founded after January 2010 (for Eurobarometer 2015) or January 2011 (for Eurobarometer 2016)	4465	0.07	0.26	0	1
11	ENVREGL	Total environmental protection expenditure by countries-sectors (source Eurostat: env_ac_epneec)	4465	6.52	18.75	0	286
12	MKT_TESTING	Market testing of a product or service before launch, as an effective public support for commercialization of innovative goods or services	4465	0.14	0.35	0	1
13	GROUP	D equals one if the company belongs to a group	4465	0.32	0.47	0	1
14	HIGHINNO	D equals one when the company invested in innovation activities more than 11% of its turnover	4465	0.09	0.28	0	1
15	TURN GROWTH > 25%	D equals one when the company reports a growth in turnover greater than 25% with respect to 2012	4465	0.10	0.30	0	1
16	TURN GROWTH 5% to 25%	D equals one when the company reports a growth in turnover greater between 5% and 25% with respect to 2012	4465	0.36	0.48	0	1
17	TURN UNCHANGED	D equals one when the company reports an unchanged turnover with respect to 2012	4465	0.35	0.48	0	1
18	TURN LOST 5% to 25%	D equals one when the company reports a loss in turnover between 5% and 25% with respect to 2012	4465	0.14	0.35	0	1
19	TURN LOST > 25%	D equals one when the company reports a loss in turnover greater than 25% with respect to 2012	4465	0.04	0.19	0	1
20	INTERNATIONAL_sales	Percentage of turnover from sales in EU or other countries	4465	34.26	37.10	0	100
21	WEAK_DISTR	D equals one in the presence of weak distribution channels that hamper the commercialization of innovative goods or services	4465	0.40	0.49	0	1

dependent variable of an additional equation to deal with its potential endogeneity. The following recursive bivariate probit is thus estimated[12]:

$$P(y_1 = 1, y_2 = 1 | x_1, x_2) = \Phi_2({x_1}'\beta_1 + \gamma y_2, {x_2}'\beta_2, \rho) \tag{2}$$

where the dependent variables are, y_1 = *EI* and y_2 = *DESIGN_inv*.

As far as the regressors of Equation (2) are concerned, x_1 comprehends the same X and Z variables of Equation (1). As for x_2, we account for the firm's decision to invest

[12]As recommended by Chiburis, Das, and Lokshin (2012), we estimated the recursive bivariate probit by bootstrapping standard errors.

Table 2. Spearman correlation matrix.

	1	2	3		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.00																				
2	−0.19	1.00																			
3	0.39	−0.33	1.00																		
4	0.69	−0.22	−0.34	1.00																	
5	0.90	−0.48	0.69	0.45	1.00																
6	−0.30	−0.05	−0.15	−0.14	−0.26	1.00															
7	−0.12	0.06	−0.06	−0.08	−0.12	−0.23	1.00														
8	0.04	0.06	0.06	−0.03	0.04	−0.24	−0.19	1.00													
9	0.16	−0.02	0.13	0.05	0.16	−0.33	−0.26	−0.27	1.00												
10	0.22	−0.03	0.02	0.20	0.17	−0.25	−0.20	−0.21	−0.29	1.00											
11	0.34	0.09	0.16	0.17	0.28	−0.19	−0.01	0.04	0.09	0.08	1.00										
12	0.03	0.10	0.06	−0.05	0.01	−0.08	0.00	0.02	0.08	−0.03	0.24	1.00									
13	−0.02	0.00	−0.04	0.02	−0.03	−0.01	0.01	0.00	0.02	−0.03	−0.06	−0.15	1.00								
14	−0.02	0.07	0.01	−0.05	−0.03	0.05	0.02	0.03	−0.01	−0.10	0.11	0.04	−0.06	1.00							
15	0.10	0.01	0.04	0.06	0.08	−0.09	0.00	0.05	0.02	0.03	0.11	0.05	0.00	0.01	1.00						
16	0.03	0.05	0.00	0.01	0.01	−0.05	0.00	−0.02	0.01	0.06	0.15	0.45	−0.04	0.06	0.05	1.00					
17	0.12	−0.06	−0.07	0.18	0.08	−0.01	0.01	−0.02	0.00	0.01	0.05	−0.04	0.02	−0.04	0.02	−0.01	1.00				
18	0.02	0.03	−0.04	0.04	0.00	−0.05	0.01	0.01	−0.02	0.05	0.05	0.01	0.10	−0.04	0.00	0.03	0.06	1.00			
19	0.07	0.01	0.03	0.04	0.06	−0.05	0.01	−0.01	0.05	0.00	0.08	0.08	−0.02	0.01	−0.02	0.05	0.01	−0.25	1.00		
20	−0.07	0.00	−0.02	−0.05	−0.06	0.07	0.00	0.00	−0.03	−0.04	−0.05	−0.03	−0.05	0.04	0.02	−0.04	−0.03	−0.24	−0.56	1.00	
21	0.00	−0.04	0.04	−0.02	0.02	0.03	−0.02	−0.01	0.00	−0.01	−0.05	−0.02	−0.02	0.01	0.03	0.00	−0.01	−0.13	−0.31	−0.30	1.00

in design, *DESIGN_inv*, using a set of theoretical consistent determinants, moving progressively from a reduced form, with only core variables, to an extended form, encompassing a set of more qualifying regressors. As for the reduced form, along with standard *Country* and *Sector* dummies, we retain that the role of design along the design ladder could be of high relevance in this respect, as anticipated in Section 2. Consequently, we expect that the absence of design use (*DESIGN_NOT_USED*) should have a negative impact on the decision to invest in it: at the lowest step of the ladder, when design is not relevant to the firm, one would expect that the firm uses its resources alternatively. In the reduced form of Equation (2), we also expect that design investments should be spurred by the successful implementation of design-related activities, such as the market testing of a product or service before launch. Although indirectly, the Innobarometer enables us to capture it by building up a dummy, *MKT_TESTING*, which takes value 1 in case firms have received an effective public support to it.

Conversely, looking at the literature on the drivers of EI, we expect that the absence of a formally recognised design activity (e.g. department) within the firm (*DESIGN_NOT_USED*) and the lack of (an effective public support to) market testing before of a product launch (*MKT_TESTING*) should not directly affect or possibly hamper the firm's capacity to eco-innovate. In other words, by retaining them incapable to affect, *per se*, the green nature of the adopted technologies, we treat these latter two variables – *DESIGN_NOT_USED* and *MKT_TESTING* – as an exclusion restriction in our recursive bivariate model (Table 5, Column (1)). In support of this choice, which remains arbitrary to a certain extent, let us notice that the Spearman correlation coefficient between EI and those two variables is actually quite low.

In order to shed further light on the determinants of design investments, we then integrate the first equation of model (2) by augmenting its reduced form incrementally. First, we expect that the international and/or innovative profile of the firms could also affect their need and/or opportunities to invest in design, and we thus regress *DESIGN_inv* against *INTERNATIONAL_sales* and *HIGH-INNO* (Table 5, Column (2)). Second, we use an additional set of information to make our model closer to a proper investment function (Table 5, Columns (3)–(5)). On the one hand, we expect that design investments are correlated with the firm's market performance, as depending on it firms could have larger (or lower) resources to finance their undertaking: accordingly, we consider as regressors the following variables which refer to different kinds of change in the firm turnover (*TURN GROWTH > 25%, TURN GROWTH 5% to 25%, TURN UNCHANGED, TURN LOST 5% to 25%, TURN LOST > 25%* – see Table 1).[13] On the other hand, we retain that design investments could be urged by the attempt at overcoming eventual problems in design-related activities, like weak distribution channels, hampering the commercialization of innovative goods or services, still captured by a dummy, *WEAK_DISTR*.

As a final control of our *DESIGN_inv* equation, we ultimately replace the *DESIGN_NOT_USED* variable with the other variables about the use of design within the firm. In doing so, we maintain that moving at progressively higher

[13]The survey does not report a continuous variable for turnover growth, but rather the set of categories we have reported above. This is a limitation of this variable, which is also discussed in the concluding section.

steps of the design ladder, and giving design a progressively more important role within the firm's business model, would possibly demand higher design investments. Accordingly, we insert among the regressors the relative variables for a progressively more central use of design, that is, *DESIGN_NOT_SYST, DESIGN_AESTHETIC, DESIGN_INTEGRAL*, and *DESIGN_CENTRAL* (Table 5, Column (6)).

Consistently with the logic of the model that we use, while estimated against the previous regressors in the first step, *DESIGN_inv* enters recursively in the second step of it, to explain the firm's propensity to eco-innovate. Indeed, should the relative tests actually signal a problem of simultaneity bias (see Section 3), this procedure would enable us to avoid biased results in the analysis of the eco-innovative impact of design, due to correlated disturbances. In doing that, the second step of the model does also comprehend the other EI determinants and controls that we have identified above (see Table 1).

Before turning to the results, it should be observed that Maddala (1983) discusses the need of an exclusion restriction in the second equation, as necessary for identification of this model. Wilde (2000) shows instead that in recursive (multiple equation) probit models with endogenous dummy regressors, no exclusion restriction for the exogenous variables is needed when the condition of sufficient variation in the data is met. More recently, Mourifié and Méango (2014) challenged the Wilde (2000) criterion and proved the necessity of an exclusion restriction to ensure point identification in this model. In light of this discussion, we chose at least an exclusion restriction to allow for the identification of parameter estimates. That was quite straightforward as *ENVREGL, GROUP, YOUNG and LSIZE* do only enter x_2 – i.e. the vector of covariates of second equation – whereas *DESIGN_NOT_USED, MKT_TESTING*, the categories of turnover growth and *WEAK_DISTR* do only enter x_1.

4. Results

A first set of results about the role of design for EI is provided by the Maximum Likelihood Estimation of the relevant parameters in the probit model (probit henceforth) of Equation (1) (Table 3). In its baseline specification (Column (1)), which controls for the structural features of the sample firms (*LSIZE* and *YOUNG*), and for two of its main drivers (*RD* and *ENVREGL*), design investments significantly and positively correlate with EI. Consistently with previous studies (see Ghisetti and Pontoni 2015), larger firms do have an advantage in eco-innovating, while age does not have a distinguishing impact for it, as also found in previous studies (e.g. Horbach 2008). *RD* is also confirmed as a significant EI determinant, while the aggregate way we tried to control for regulations does not. In this relatively consistent picture, having an economically recognizable investment in design (>1% of turnover) is significantly associated to firms with a higher propensity to eco-innovate. This supports our main research hypothesis: allocating resources to design development significantly correlates with its eco-impact in terms of EI.

The evidence about the correlation between EI and design persists by augmenting the model with the progressive insertion of other candidate drivers and controls, that is, *INTERNATIONAL_sales* (Column (2)), *GROUP* (Column (3)), and *HIGHINNO* (Column (4)). Out of them, a significant effect emerges only from the presence of

Table 3. Eco-innovation and design: Probit estimated coefficients.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DESIGN_inv	0.2547***	0.2540***	0.2544***	0.2446***	0.2244***	0.1966***	0.4834***	0.2640***
	(0.0412)	(0.0412)	(0.0412)	(0.0414)	(0.0433)	(0.0427)	(0.0986)	(0.0440)
LSIZE	0.1327***	0.1228***	0.1215***	0.1266***	0.1278***	0.1279***	0.1623***	0.1367***
	(0.0130)	(0.0141)	(0.0152)	(0.0153)	(0.0153)	(0.0153)	(0.0205)	(0.0162)
RD	0.1780***	0.1716***	0.1715***	0.1626***	0.1551***	0.1618***	0.1572***	0.2039***
	(0.0450)	(0.0451)	(0.0451)	(0.0453)	(0.0457)	(0.0454)	(0.0454)	(0.0473)
ENVREGL	0.0009	0.0008	0.0008	0.0009	0.0010	0.0009	0.0010	
	(0.0014)	(0.0014)	(0.0014)	(0.0014)	(0.0014)	(0.0014)	(0.0014)	
YOUNG	−0.0332	−0.0317	−0.0327	−0.0359	−0.0317	−0.4030***	−0.0382	−0.0553
	(0.0767)	(0.0769)	(0.0769)	(0.0768)	(0.0771)	(0.1177)	(0.0770)	(0.0809)
INTERNATIONAL_sales		0.0012*	0.0012*	0.0010*	0.0011*	0.0011*	0.0011*	0.0005
		(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0007)
GROUP			0.0113	0.0081	−0.0009	0.0045	0.0038	0.0037
			(0.0485)	(0.0486)	(0.0488)	(0.0486)	(0.0486)	(0.0521)
HIGHINNO				0.2680***	0.2660***	0.2782***	0.2642***	0.3182***
				(0.0686)	(0.0688)	(0.0690)	(0.0686)	(0.0730)
DESIGN_NOT_SYST					0.0482			
					(0.0644)			
DESIGN_AESTHETIC					0.0059			
					(0.0651)			
DESIGN_INTEGRAL					0.0488			
					(0.0589)			
DESIGN_CENTRAL					0.1692**			
					(0.0669)			
YOUNG*DESIGN_inv						0.7033***		
						(0.1600)		
LSIZE*DESIGN_inv							−0.0650***	
							(0.0242)	
Constant	−0.9607***	−0.9719***	−0.9692***	−1.0056***	−1.0532***	−0.9890***	−1.1362***	−0.8371***
	(0.1077)	(0.1080)	(0.1085)	(0.1092)	(0.1137)	(0.1099)	(0.1202)	(0.2292)
N	4465	4465	4465	4465	4465	4465	4465	4465
pseudo R^2	0.0565	0.0570	0.0570	0.0595	0.0608	0.0629	0.0607	0.1039

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Although not reported, 27 country dummies and 7 sector dummies (CA, CB, CC, CD-CG, CH, CI-CL, CM in Nace Rev 2) are included in Columns (1)-(7). Column (8), instead, includes the full set of interactions between 27 country and 7 sector dummies, by excluding ENVREGL which was constructed at the country-sector level.

Table 4. Eco-innovation and design: Probit-based estimated marginal effects.

	(1)	(2)	(3)	(4)	(5)	(6)
DESIGN_inv	0.0937***	0.0934***	0.0935***	0.0897***	0.0821***	0.0921***
LSIZE	0.0488***	0.0451***	0.0447***	0.0464***	0.0468***	0.0477***
RD	0.0657***	0.0633***	0.0633***	0.0599***	0.0570***	0.0714***
ENVREGL	0.0003	0.0003	0.0003	0.0003	0.0004	
YOUNG	−0.0122	−0.0116	−0.0120	−0.0131	−0.0116	−0.0192
INTERNATIONAL_sales		0.0004*	0.0004*	0.0004*	0.0004*	0.0002
GROUP			0.0042	0.0030	−0.0003	0.0013
HIGHINNO				0.0997***	0.0988***	0.1124***
DESIGN_NOT_SYST					0.0176	
DESIGN_AESTHETIC					0.0022	
DESIGN_INTEGRAL					0.0178	
DESIGN_CENTRAL					0.0619**	
N	4465	4465	4465	4465	4465	4465

(1) Average marginal effects (dy/dx) of all covariates on the discrete change of EI from 0 to 1 are reported. Note: dy/dx for dichotomous variables is the discrete change from the base level 0.
*(2) In order to provide an interpretable effect of the interaction variables YOUNG*DESIGN_inv and LSIZE*DESIGN_inv (Table 3, Column (6) and (7)), this is only reported in a visual way in Figures 1 and 2.*
(3) Column (6) reports the average marginal effects of Column (8) specification in Table 3.

other high innovative investments (*HIGHINNO*) in addition to *RD* and *DESIGN_inv*, confirming previous evidence on the 'costly' nature of the EI process (Gagliardi, Marin, and Miriello 2016). The previous results are confirmed also when controlling for the full set of interactions between country and sector dummies (Column (8)). This could be actually considered as an alternative to the environmental regulation variable, *ENVREGL*, constructed at the country-sector level, as it would capture most of the existing regulations. Last, but not least, *DESIGN_inv* keeps its highly significant correlation with *EI* when the use of design along the relative ladder is controlled for (Column (5)). Quite interestingly, and still consistently with our expectation, the only specification in the use of design that turns out significant is the one that alludes to its centrality within the firm (*DESIGN_CENTRAL*). According to the organizational literature on eco-design, the integration of design and environmental capabilities seems to call for a pivotal role of design within the firm.

Previous results find further interesting specifications when their marginal effects are calculated (Table 4).

Not only correlates design significantly with EI, but its marginal effect on it appears greater than that of R&D investments, and similar to that of other (high) innovative investments (*HIGHINNO*). Thinking about the primary driving role that R&D is usually recognised in innovation and eco-innovation studies, this result appears of great importance. Consistently with some seminal papers in innovation economics (Walsh et al. 1992; Von Hippel 1998), design could surpass the innovation effect of R&D by allowing firms to discover the customer-market potential of new product development. On the other hand, marginal effects also show that the centrality of design within the firm appears of even greater importance than design investments for the adoption of EI. Also with respect to EI, as for standard innovations (Montresor and Vezzani 2017), the innovative value of this intangible asset relies on the way it is managed more than on the amount of resources invested in it.

Interesting insights also emerge from the analysis of the moderation effects that *YOUNG* and *LSIZE* exert on the relationship between *DESIGN_inv* and EI

(Columns (6) and (7)). As Table 3 shows, the coefficients of the interaction terms *YOUNG*DESIGN_inv* and *LSIZE*DESIGN_inv* are both significant, positive and negative, respectively. However, the direction of the effect and its statistical significance cannot be directly assessed from Tables 3 and 4 (see Zelner 2009 for a discussion). Accordingly, we have followed the approach by Ai and Norton (2003) and Norton, Wang, and Ai (2004) to visualize the 'correct' interaction effect with respect to *YOUNG* (Figure 1) and *LSIZE* (Figure 2).[14] In this last respect, it should be retained that, as Greene (2010, 291) remarks with respect to the interaction effect of non-linear models, there will still be 'a missing element in the measure of partial effects – the "unit change" in the relevant variable may itself be unreasonable' and thus 'graphical devices may be much more informative than the test statistics'.

As for the moderation effect of *YOUNG*, it emerges that the average interaction term is always positive (left-hand side of Figure 1) and generally significant, though with the previous caveat (right-hand side of Figure 1), and that remarkable variation emerges across firms. Considering that *YOUNG*, in isolation, is not significant (see Table 3, Column (1)), this finding suggests that being young only matters insofar it allow firms more 'degrees of freedom' than older ones, in directing their design investment towards EI. These degrees of freedom could actually be reduced by a longer experience with a possibly standard (e.g. non-green) use of design, given the relevance of path-dependence phenomena in building up design competencies.

On the other hand, Figure 2 shows that, in most of the cases, the moderation effect that size plays on our focal relationship is negative (left-hand side of Figure 2). However, the same effect does not appear statistically significant (right-hand side of Figure 2). In other words, no moderation effect seems to be at work when the role of size is considered. As *LSIZE* is significantly correlated with EI (see Table 3, Column (1)), we can just conclude that larger firms are 'apparently' more eco-innovative.

Summing up, probit results already provide us with general support to our research hypotheses about the eco-innovative role of design. However, as we said in the previous Section, these results could be affected by the endogeneity of our focal regressor, *DESIGN_inv*. Indeed, when a bivariate probit is applied to address this problem, evidence of a simultaneity bias is actually found. The Wald statistics for the hypothesis that ρ – i.e. the correlation between the disturbances of the two equations – is equal to 0 cannot be rejected in most of our estimation results (Greene 2008). The Rao score test performed to detect whether our models are miss-specified and the relative estimations thus inconsistent, does not reject the goodness of fit for all of our estimate specifications.[15]

The choice of a bivariate probit, to which we had alluded in Section 3, is thus motivated. Quite interestingly, as Table 5 reveals, its results appear generally consistent with our expectations.

Let us recall that the results of Table 5 are reported in the previously discussed order, with respect to the second equation of Model (2), aimed at estimating the determinants of

[14]This why Table 4 only reports marginal effects for the first 5 columns, as the interaction effects are better captured through the *ad-hoc* analysis reported in Figures 1 and 2.

[15]This test is performed using the Stata postestimation command scoregof developed by Murphy (2007) to compute the goodness-of-fit score test applicable to bivariate probit models (Chiburis 2010, Chiburis, Das, and Lokshin 2012).

Table 5. Eco-innovation and design: Bivariate probit results.

Step 2: EI equation	(1)	(2)	(3)	(4)	(5)	(6)
DESIGN_inv	0.4736***	0.4659***	0.8116***	0.6728***	0.9616***	0.5849***
	(0.1558)	(0.1728)	(0.1646)	(0.1467)	(0.1635)	(0.1389)
LSIZE	0.1313***	0.1252***	0.1298***	0.1225***	0.1569***	0.1230***
	(0.0139)	(0.0126)	(0.0139)	(0.0143)	(0.0203)	(0.0128)
RD	0.1683***	0.1529***	0.1685***	0.1342***	0.1294***	0.1427***
	(0.0440)	(0.0430)	(0.0492)	(0.0363)	(0.0490)	(0.0406)
YOUNG	−0.0354	−0.0383	−0.0583	−0.4011***	−0.0437	−0.0383
	(0.0860)	(0.0596)	(0.0797)	(0.1094)	(0.0786)	(0.0789)
ENVREGL	0.0010	0.0009		0.0010	0.0010	0.0010
	(0.0014)	(0.0013)		(0.0015)	(0.0013)	(0.0014)
INTERNATIONAL_sales		0.0010	0.0003	0.0009	0.0009	0.0010
		(0.0007)	(0.0008)	(0.0007)	(0.0007)	(0.0007)
GROUP		0.0064	−0.0016	0.0007	−0.0002	0.0033
		(0.0405)	(0.0437)	(0.0525)	(0.0440)	(0.0488)
HIGHINNO		0.2360***	0.2282**	0.2043***	0.1899***	0.2164***
		(0.0798)	(0.0980)	(0.0662)	(0.0711)	(0.0637)
YOUNG*DESIGN_inv				0.6874***		
				(0.1465)		
DESIGN_inv*LSIZE					−0.0650***	
					(0.0231)	
Constant	−1.0466***	−1.0856***	−1.0239***	−1.1456***	−1.2932***	−1.1204***
	(0.1210)	(0.1265)	(0.2658)	(0.1172)	(0.0997)	(0.0956)
			Step 1: Design investment equation			
DESIGN_NOT_USED	−0.7905***	−0.7885***	−0.7433***	−0.7480***	−0.7472***	
	(0.0533)	(0.0426)	(0.0522)	(0.0506)	(0.0624)	
DESIGN_NOT_SYST						0.2283***
						(0.0615)
DESIGN_AESTHETIC						0.7286***
						(0.0580)
DESIGN_INTEGRAL						0.9576***
						(0.0537)
DESIGN_CENTRAL						1.0723***
						(0.0676)
MKT_TESTING	0.2194***	0.2101***	0.1995***	0.1947***	0.1947***	0.1880***
	(0.0531)	(0.0579)	(0.0511)	(0.0636)	(0.0543)	(0.0565)
INTERNATIONAL_sales		0.0011	0.0010	0.0010*	0.0010	0.0009
		(0.0007)	(0.0006)	(0.0006)	(0.0007)	(0.0006)
HIGHINNO		0.3869***	0.3888***	0.3865***	0.3868***	−0.0318
		(0.0753)	(0.0633)	(0.0656)	(0.0732)	(0.0721)
TURN GROWTH > 25%			−0.0223	−0.0185	−0.0173	0.1449***
			(0.0688)	(0.0591)	(0.0704)	(0.0489)
TURN GROWTH 5% to 25%			0.1721***	0.1629***	0.1637***	0.0973
			(0.0529)	(0.0503)	(0.0450)	(0.0595)
TURN LOST 5% to 25%			0.1025	0.0988	0.1004*	−0.1538
			(0.0710)	(0.0626)	(0.0584)	(0.1184)
TURN LOST > 25%			−0.1292	−0.1441	−0.1440	0.4051***
			(0.1027)	(0.0960)	(0.1085)	(0.0709)
WEAK_DISTR			0.1963***	0.1927***	0.1946***	0.1469***
			(0.0340)	(0.0407)	(0.0405)	(0.0427)
Constant	0.0074	−0.0764	−0.2000*	−0.1936*	−0.1948	−0.9476***
	(0.0992)	(0.1117)	(0.1143)	(0.1051)	(0.1306)	(0.0972)
Rho	−0.1437	−0.1450	−0.3809***	−0.3245***	−0.3268***	−0.2354**
	(0.1043)	(0.1132)	(0.1238)	(0.1034)	(0.1097)	(0.0978)
N	4465	4465	4465	4465	4465	4465
Average marginal effect of DESIGN_inv on EI	0.082	0.084	0.076	0.076	0.077	0.074
Wald test of rho = 0 Chi_2	1.93	1.98	11.46	9.55	9.72	8.17
Wald test of rho = 0 p> Chi_2	0.16	0.15	0.00	0.00	0.00	0.00
Murphy's score test for biprobit Chi_2	17.96	14.81	17.24	19.07	17.31	26.87
Murphy's score test for biprobit p> Chi_2	0.03	0.09	0.04	0.02	0.04	0.00

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*
Although not reported, 27 country dummies and 7 sector dummies (CA, CB, CC, CD-CG, CH, CI-CL, CM in Nace Rev 2) are included in Columns (1)-(6). Column (3), instead, includes the full set of interactions between 27 country and 7 sector dummies, by excluding ENVREGL which was constructed at the country-sector level.

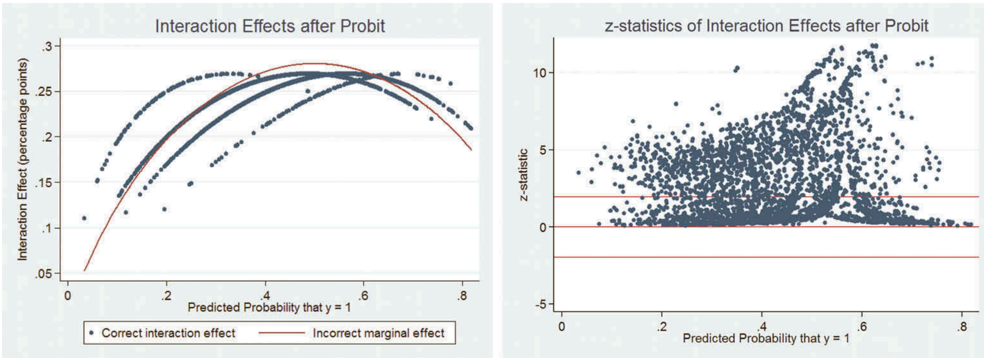

Figure 1. Marginal effects of the interaction between YOUNG and DESIGN_inv.

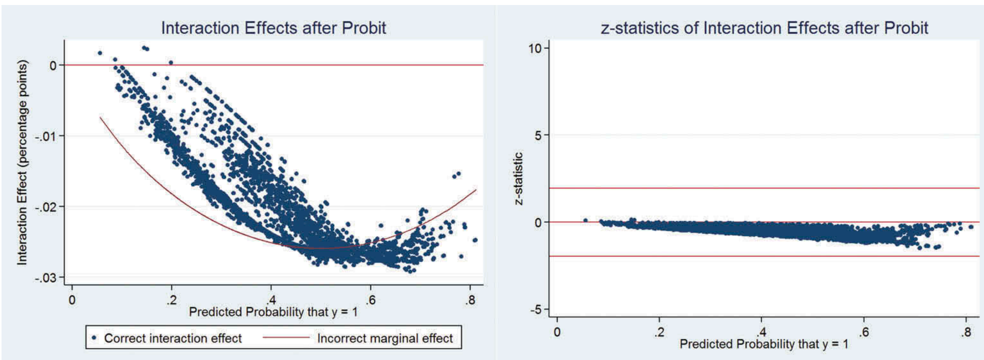

Figure 2. Marginal effects of the interaction between LSIZE and DESIGN_inv.

EI. As for the first equation of the same model, about the determinants of *DESIGN_inv*, still consistently with what announced in Section 3, we have started reporting its results from a reduced form of it (Column (1), lower part of Table 5) which includes two variables along with country and sector dummies: the absence of design relevance within the firm (*DESIGN_NOT_USED*) and the presence of a successful approach to market testing (*MKT_TESTING*). We have then moved to the results of its progressive augmentation (from Column (2) to (5)) for the sake of a robustness check.

Starting with the results of the first equation (lower panel of Table 5), as expected, design investments turns out to be negatively correlated with the absence of design relevance within the firm (*DESIGN_NOT_USED*). On the other hand, design investments appear higher for firms having a successful approach to market testing (*MKT_TESTING*), still as expected.

Looking at the other arguments of the design investment function we have been able to address with the Innobarometer, results are only partially confirmed. Operating on international markets (*INTERNATIONAL_sales*) is mostly not significant, while relevant is again the effect of high investments in innovation (*HIGHINNO*), which thus seem complementary to design investments. A positive market performance of the investing firm matters, but providing it is moderate (*TURN GROWTH 5% to 25%*). Firms with the highest turnover growth (*TURN GROWTH > 25%)* instead seem to move away from design investments to other resource allocations, suggesting that design could be substituted with other strategic drivers (i.e. other intangibles) when growing at fast rates. Finally, the explanatory role of the design-related activities we have been able to capture turns out to be confirmed when the latter set of controls is retained. Not only remains *MKT_TESTING* significant, but design investments are also more likely to occur in firms for which design investments could be a mechanism to overcome problems of weak distribution channels (*WEAK_DISTR*).

As for the final extension of the *DESIGN_inv* function (Column (6)), our argument about the 'structural' position of design in the firm's business model gets substantially confirmed. While a non-systematic use of design (*DESIGN_NOT_SYST*) correlates positively with *DESIGN_inv*, this is progressively more so for a progressively more integral use of design after that level (*DESIGN_AESTHETIC, DESIGN_INTEGRAL*, and *DESIGN_CENTRAL*).

Overall, we can conclude that the predictors we have identified to make design investment exogenous work relatively well. On this basis, we can more safely look at the effect of *DESIGN_inv* in accounting for EI in the second step of the model (upper panel of Table 5). The results that we got are even more reassuring than the previous ones: having controlled for reverse causality, EI could be claimed to be driven by the firms' investment in design. Allocating time and money to design projects could possibly increase the firms' familiarity with practices for increasing the eco-innovative impact of design (among which, eco-design could also appear) and possibly push them towards their adoption. However, as the kind of projects to which our variable refers are presumably of a wider domain, and not necessarily with this specific target, it seems that design could more generally work as a channel through which firms can increase their creative thinking in the green realm (Beard and Hartmann 1997).

Once again, the significance of *DESIGN_inv* is confirmed when we augment the baseline specification (including *SIZE, YOUNG, RD* and *ENVREGL*) by including all of the other remaining regressors (*INTERNATIONAL_sales, GROUP* and *HIGHINNO*). On the other hand, having controlled for the endogeneity of *DESIGN_inv*, and having plugged the use of design among its determinants, some interesting changes occur with respect to these regressors. In particular, when we try to address its moderation effect on the EI impact of *DESIGN_inv, YOUNG* turns out to be weakly significant *per se*, but this time with a negative sign. This reverses the argument that previously emerged from the probit estimates, without controlling for the endogeneity of *DESIGN_inv*. Retaining this an important issue to address, this last result appears more reliable and points to an experience advantage of older firms in the EI domain, which has recently been identified by other studies (see Leoncini et al. 2017).

Before concluding, a set of robustness checks of our benchmark estimates are run. First of all, we consider whether results are confirmed when a more specific kind of EI is addressed, for which the effect of design could be more salient and thus less confounded by other mechanisms, that is product EI. As is well known, design is actually a crucial input in new product development rather than in the introduction of new processes. In the absence of a specific survey question on the adoption of product 'eco-innovations', we could only build up an indirect proxy of the presence of product '*eco-innovators*' by crossing the focal question on the firm's adoption of sustainable technologies, with that on the firm's introduction of product rather than process innovations in general, without the chance of distinguishing their green vs. non-green nature. Although with an extreme simplification, we assume that a product eco-innovator could be at least signalled by a 'standard' product innovator, which has declared to have adopted sustainable technologies too. Similarly, we assume that a process innovator that has adopted sustainable technologies could proxy the presence of a process eco-innovator.

While it could be in principle interesting to re-run our estimates by sharply distinguishing product from process innovators in the adoption of sustainable technologies, this is in practice unfeasible. This is due to the fact that, in our sample of 4465 firms, we observe 1567 product and 2922 process innovators, with as many as 1202 firms (nearly ¼) being both product and process innovators (see Table A3 in the Appendix). On this basis, excluding from the estimates all those firms that are not product (not process) innovator will create a sever selection bias, which would prevent us from drawing generalizable results. As a way to overcome this problem, we have filtered our sample in two different ways. First of all, we have first excluded those 1720 firms that declared to be process but not product innovators, that is, of being exclusive process innovators, and run the estimates with respect to *No-ExclEIPROC*. Similarly, we have then left out those 365 sample firms that are exclusive product innovators (i.e. product but no process innovators), and run the estimates with respect to *No-ExclEIPROD*. As Table 6 reveals, the role of design investments in driving EI seems to emerge significant and positive in both cases. All in all, this suggests that the results we got are not dependent on the kind of eco-innovator – product rather than process – that we consider.

We run a second robustness check in the attempt of retaining the country – and industry-specific context in which our focal relationship between design investments and EI unfolds. As for the former, the best we could do with the number of available observations was to split the sample in two, by distinguishing firms in the EU15 block – that it, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom – from those in the 13 EU post accession countries. While these remain two aggregate and heterogeneous sets of countries, running model (2) with respect to the two samples, enables us to partially address the lack in the extant literature of comparative evidence on EI in the presence of different economic conditions (Del Río, Peñasco, and Romero-Jordán 2016).

Quite interestingly, Table 7 shows that the investigated geographical context does actually make an important difference. The design investment function (Step 2) of the companies that operate in the countries at the periphery of the EU does still rely on the use of design, as much as that of the EU15, but on a lesser number of the other regressors. In the former context, investing in design appears a decision that only depends on the extent at which design is actually 'developed' within the firm, irrespectively from other 'external' considerations (e.g. turnover trend). In the same group of non-EU15 countries, which are generally marked by less complex innovation processes than the EU15, design does not appear to have developed so much to make of the relevant investments a significant driver of EI (Step 1): indeed, EI rather keeps on depending, unlike the EU15, on standard R&D investments. Quite interestingly, when the two samples are distinguished, environmental regulation for the first time appears significant, but only in the EU15 countries. In the

Table 6. Design and eco-innovation by type of firm, no exclusive process innovators (No-ExclEIPROC, Columns (1) – (3)) and no exclusive product innovators (No-ExclEIPROD, Columns (4) – to (6)): Bivarite probit results.

	(1)	(2)	(3)	(4)	(5)	(6)
Step 2: EI equation	No-ExclEIPROC	No-ExclEIPROC	No-ExclEIPROC	No-ExclEIPROD	No-ExclEIPROD	No-ExclEIPROD
DESIGN_inv	0.5368***	0.5428**	0.9260***	0.4425***	0.4357**	0.7195***
	(0.1900)	(0.2207)	(0.2361)	(0.1571)	(0.1776)	(0.1874)
LSIZE	0.1434***	0.1388***	0.1402***	0.1229***	0.1158***	0.1216***
	(0.0195)	(0.0175)	(0.0283)	(0.0127)	(0.0168)	(0.0181)
RD	0.1833***	0.1756***	0.1507*	0.1874***	0.1694***	0.1984***
	(0.0591)	(0.0629)	(0.0856)	(0.0465)	(0.0527)	(0.0628)
YOUNG	−0.1403	−0.1408*	−0.1573*	−0.0864	−0.0908	−0.1248
	(0.0988)	(0.0837)	(0.0901)	(0.0828)	(0.0792)	(0.1009)
ENVREGL	0.0009	0.0009		0.0011	0.0011	
	(0.0018)	(0.0019)		(0.0013)	(0.0014)	
INTERNATIONAL_sales		0.0001	0.0000		0.0012	0.0007
		(0.0009)	(0.0008)		(0.0008)	(0.0007)
GROUP		0.0304	0.0044		0.0047	0.0130
		(0.0587)	(0.0645)		(0.0608)	(0.0382)
HIGHINNO		0.1032	0.1590		0.2517***	0.2443***
		(0.1091)	(0.1164)		(0.0795)	(0.0937)
Constant	−1.0606***	−1.0671***	−0.8862***	−0.9860***	−1.0348***	−0.8732***
	(0.1499)	(0.1521)	(0.2755)	(0.1147)	(0.1177)	(0.2800)
Step 1: Design investment equation						
DESIGN_NOT_USED	−0.8737***	−0.8714***	−0.8160***	−0.7921***	−0.7904***	−0.7514***
	(0.0586)	(0.0703)	(0.0429)	(0.0520)	(0.0503)	(0.0593)
MKT_TESTING	0.1771**	0.1673**	0.1387**	0.2519***	0.2428***	0.2351***
	(0.0754)	(0.0744)	(0.0656)	(0.0542)	(0.0611)	(0.0722)
INTERNATIONAL_sales		0.0014*	0.0013*		0.0007	0.0006
		(0.0008)	(0.0007)		(0.0006)	(0.0008)
HIGHINNO		0.4146***	0.4218***		0.3630***	0.3642***
		(0.0843)	(0.1224)		(0.0809)	(0.0836)
TURN GROWTH > 25%			−0.0448			−0.0166
			(0.0485)			(0.0730)
TURN GROWTH 5% to 25%			0.1158			0.1688***
			(0.0767)			(0.0552)
TURN LOST 5% to 25%			0.0112			0.0594
			(0.0809)			(0.0719)

(*Continued*)

Table 6. (Continued).

	(1)	(2)	(3)	(4)	(5)	(6)
Step 2: EI equation	No-ExclEIPROC	No-ExclEIPROC	No-ExclEIPROC	No-ExclEIPROD	No-ExclEIPROD	No-ExclEIPROD
TURN LOST > 25%			−0.1664			−0.2238*
			(0.1102)			(0.1171)
WEAK_DISTR			0.2941***			0.1618***
			(0.0704)			(0.0486)
Constant	0.0060	−0.0859	−0.2346***	0.0180	−0.0520	−0.1474
	(0.1270)	(0.1183)	(0.0729)	(0.0903)	(0.1104)	(0.1254)
Rho	−0.1165	−0.1227	−0.3943**	−0.1418	−0.1430	−0.3361***
	(0.1225)	(0.1514)	(0.1957)	(0.1054)	(0.1121)	(0.1254)
N	2745	2745	2745	4100	4100	4100
Average marginal effect of DESIGN_inv on EI	0.125	0.123	0.104	0.079	0.075	0.066
Wald test of rho = 0 Chi2	0.88	0.98	7.78	1.83	1.87	8.99
Wald test of rho = 0 p> Chi_2	0.34	0.32	0.00	0.17	0.17	0.00
Murphy's score test for biprobit Chi_2	10.91	9.91	10.79	17.20	15.93	25.18
Murphy's score test for biprobit p> Chi_2	0.28	0.35	0.29	0.04	0.06	0.00

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Although not reported, 27 country dummies and 7 sector dummies (CA, CB, CC, CD-CG, CH, CI-CL, CM in Nace Rev 2) are included in Columns (1)-(6). Column (3) and (6), instead, include the full set of interactions between 27 country and 7 sector dummies, by excluding ENVREGL which was constructed at the country-sector level.

Table 7. Eco-innovation and design by macro area, EU15 vs rest of EU: Bivariate probit results.

	(1)	(2)
Step 2: EI equation	EU15	OTHER_EU
DESIGN_inv	0.9987***	−0.1902
	(0.2083)	(0.2460)
RD	0.0710	0.2396***
	(0.0619)	(0.0498)
ENVREGL	0.0025**	0.0029
	(0.0010)	(0.0045)
INTERNATIONAL_sales	0.0016*	−0.0009
	(0.0008)	(0.0008)
GROUP	0.0003	−0.0964
	(0.0501)	(0.0760)
HIGHINNO	0.0818	0.2870***
	(0.0900)	(0.0870)
LSIZE	0.1247***	0.1276***
	(0.0183)	(0.0252)
YOUNG	−0.3276***	0.1802
	(0.0900)	(0.1203)
Constant	−1.3056***	−0.6811***
	(0.0837)	(0.1410)
Step 1: Design investment equation		
DESIGN_NOT_SYST	−0.7413***	−0.7708***
	(0.0687)	(0.0771)
MKT_TESTING	0.1463**	0.2664***
	(0.0710)	(0.0613)
INTERNATIONAL_sales	0.0013*	0.0009
	(0.0008)	(0.0009)
TURN GROWTH >25%	0.0926	−0.0670
	(0.1051)	(0.1065)
TURN GROWTH 5% to 25%	0.2809***	−0.0133
	(0.0509)	(0.0647)
TURN LOST 5% to 25%	0.2200***	−0.0390
	(0.0705)	(0.0997)
TURN LOST >25%	−0.0074	−0.2943**
	(0.1097)	(0.1389)
HIGHINNO	0.5036***	0.2820***
	(0.1118)	(0.0939)
WEAK_DISTR	0.1934***	0.1306*
	(0.0547)	(0.0760)
Constant	−0.1537	−0.0633
	(0.1062)	(0.1417)
Rho	−0.5932***	0.2849
	(0.2073)	(0.1860)
N	2564	1901
Average marginal effect of DESIGN_inv on EI	0.052	0.103
Wald test of rho = 0 Chi2	18.07	5.49
Wald test of rho = 0 p> Chi_2	0.00	0.02
Murphy's score test for biprobit Chi_2	32.75	3.17
Murphy's score test for biprobit p> Chi_2	0.00	0.95

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*
Although not reported, 27 country dummies and 7 sector dummies (CA, CB, CC, CD-CG, CH, CI-CL, CM in Nace Rev 2) are included.

same setting, incumbents firms are more eco-innovative than young firms, while no significant difference emerges in the EU13.

As far as the role of the industry-context is concerned, data availability still prevented us from distinguishing sample firms in a more sophisticated way than by 'high', 'medium/high', 'medium/low' or 'low' technological sectors, as from the OECD classification (Hatzichronoglou 1997). When we run separate estimates for the four relative samples, Table 8 shows that the relationship between EI and design is also industry-specific to a notable extent. On the one hand, in high-tech industries the design function of companies is exceptionally unaffected by the use they make of it (Step 1) and is rather influenced by few other non-design related determinants, such as turnover trend and other innovation investments. On the other hand, and confirming our main results, design investments do matter for the sake of EI across all the sectors (Step 2), with remarkable differences in the role of the other EI drivers (namely *RD, HIGHINNO* and *INTERNATIONAL_sales*).

Like in the case of the other groups of sectors, and for the distinction between groups of countries that we were able to observe, results are merely informative of context-specific considerations. More disaggregated data than those available from the Innobarometer would actually be necessary to address these aspects more carefully in future research.

5. Conclusions

The impact that design can exert on eco-innovation does not exhaust in the simple 'integration' of an environmental concern in product development and/or process planning, as the 'packed' notion of eco-design would instead suggest. The issue is not just that of identifying the proper technique and procedure to make this integration happen and/or to devise suitable policy schemes (e.g. eco-design regulations) to make firms internalise the externalities of eco-design. Taking a wider perspective than the one actually prevailing in environmental economics, and eclectically combining recent research streams on eco-innovation and on intangibles, the eco-impact of design can be looked in a less 'black-boxed' way. In an 'un-packed' way, this actually appears as a relationship between, on the one hand, the eco-innovations that firms introduce, on the other hand, the economic and organisational choices they make with respect to an important intangible asset like design.

In this paper we have addressed this relationship and put forward positive expectations about its holding. Even when they are not explicitly dedicated to formal eco-design practices, design investments could help firms discover new technological opportunities and solutions with a favourable environmental impact. Furthermore, a positive relationship between environmental performances and design can be helped by using design as a pivotal business activity and giving it a core role within the organisation of the firm.

Pooling the Eurobarometer 2015 and 2016 surveys, we have been able to submit these expectations to a first but wide and systematic empirical test. By referring to about 4500 European and non-European firms in the period 2012–2015, we have actually made an important step ahead with respect to the dominant use of case-study evidence in the extant literature.

Overall, the results we have obtained are supportive of the actual existence of a positive relationship between design and eco-innovation. Investing in design is actually associated with a greater capacity of eco-innovating, apparently more than for other standard eco-innovation drivers, like R&D. These investments also depend on

Table 8. Eco-innovation and design by sector of OECD technological intensity: Bivariate probit results.

	(1)	(2)	(3)	(4)
Step 2 – EI equation	HIGH-TECH	LOW-TECH	MEDIUM/HIGH-TECH	MEDIUM/LOW-TECH
DESIGN_inv	1.2384***	0.9141***	0.8687**	0.5710**
	(0.1393)	(0.2169)	(0.4146)	(0.2282)
RD	−0.1091	0.1352**	0.3373***	0.0553
	(0.1960)	(0.0633)	(0.1105)	(0.0730)
ENVREGL	0.0222	0.0039**	0.0005	−0.0019
	(0.0197)	(0.0016)	(0.0014)	(0.0025)
INTERNATIONAL_sales	0.0027	0.0018**	0.0022*	−0.0010
	(0.0026)	(0.0009)	(0.0013)	(0.0010)
GROUP	−0.1812	0.0821	−0.1721*	−0.0173
	(0.1562)	(0.0743)	(0.0917)	(0.0766)
HIGHINNO	0.0520	0.0368	−0.0186	0.4655***
	(0.2579)	(0.1111)	(0.1765)	(0.1209)
Lsize	0.2279***	0.1017***	0.0724**	0.1731***
	(0.0561)	(0.0218)	(0.0313)	(0.0252)
YOUNG	−0.3350	0.0275	0.0528	−0.2079*
	(0.6098)	(0.1146)	(0.1838)	(0.1175)
Constant	−1.9639***	−1.2391***	−1.2007***	−1.0497***
	(0.2696)	(0.1084)	(0.2012)	(0.1119)
Step 1: Design investment equation				
DESIGN_NOT_USED	−0.4122	−0.7361***	−0.6058***	−0.7685***
	(0.2652)	(0.0832)	(0.1230)	(0.0773)
MKT_TESTING	0.2708	0.1817**	0.0539	0.3803***
	(0.2552)	(0.0869)	(0.1084)	(0.1073)
INTERNATIONAL_sales	−0.0049*	0.0006	0.0002	0.0020**
	(0.0026)	(0.0009)	(0.0012)	(0.0009)
TURN GROWTH > 25%	0.2660	0.2256**	−0.1191	−0.1448
	(0.2624)	(0.1085)	(0.1569)	(0.1150)
TURN GROWTH 5% to 25%	0.6652***	0.2410***	0.1603	0.0742
	(0.1521)	(0.0690)	(0.1091)	(0.0786)
TURN LOST 5% to 25%	0.4504	0.1796*	0.0948	0.1683*
	(0.3290)	(0.0918)	(0.1388)	(0.1022)

(*Continued*)

Table 8. (Continued).

	(1)	(2)	(3)	(4)
Step 2 – EI equation	HIGH-TECH	LOW-TECH	MEDIUM/HIGH-TECH	MEDIUM/LOW-TECH
TURN LOST > 25%	0.1853	−0.1206	−0.1271	−0.0697
	(0.2456)	(0.1700)	(0.2132)	(0.1604)
HIGHINNO	0.6743**	0.3501***	0.4641***	0.1800
	(0.3272)	(0.1128)	(0.1569)	(0.1224)
WEAK_DISTR	0.0966	0.1043*	0.2269**	0.2261***
	(0.1485)	(0.0617)	(0.0934)	(0.0667)
Constant	0.3033*	−0.0100	0.0687	−0.1072
	(0.1730)	(0.0642)	(0.1078)	(0.0742)
Rho	−12.6410	−0.4200**	−0.4758	−0.2604
	(499.8711)	(0.1726)	(0.3473)	(0.1592)
N	183	1819	875	1588
Average marginal effect of DESIGN_inv on EI	−0.176	0.107	0.061	0.059
Wald test of rho = 0 Chi2	0.00	5.92	1.87	2.67
Wald test of rho = 0 p> Chi_2	0.98	0.01	0.17	0.10

*Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

Because of convergence problems, given the limited sample size in some specifications (col. 1), we could not include country and sector dummies. Accordingly, the results of this table are meant to be preliminary and call for future research.

the way design is used within the firm, which thus also matters for its eco-innovative impact. Last, but not least, while the focal relationship between EI and design appears robust with respect to the different kinds of 'eco-innovators' we have been able to consider, an interesting variability seems to emerge when country and industry specificities are considered to a preliminary extent.

From an academic point of view, these results contribute to two streams of literature. First of all, we add to the growing research on the determinants and drivers of EI, in which design has so far found attention mainly in theoretical terms (see, for example, Carrillo, Del Río González, and Könnölä 2009) and, in empirical terms, only with respect to specific geographical contexts and indistinguishably from other non-R&D activities (see, for example, Marzucchi and Montresor 2017). Second, we also add to a still 'thin' body of management literature (Boks 2006), in which the use and role of design within the firm has been so far only marginally addressed and mainly through dedicated case-studies (see, for example, Johansson and Magnusson 2006; Tingström, Swanström, and Karlsson 2006).

The results we obtained have important strategic and policy implications. In strategic terms, the successful implementation of an innovative and environmentally sustainable use of design, requires firms to equip with design competencies and design-oriented business models and organisational structures. The amount of resources firms decide to invest in design, and not only in the development/adoption of specific eco-design techniques, thus becomes a crucial aspect. In the same respect, the use firms make of design in general within the firm, that is, in terms of centrality in the design ladder model, reveals as much important for its effective eco-impact.

From a policy point of view, the current spectrum of eco-design interventions appears limited. On the one hand, their fields of application seem to require an extension with respect to the specific domains in which it has so far concentrated, at least in Europe (e.g. eco-labelling and energy-labelling). On the other hand, while making firms aware of the opportunities to extend the environmental dimension to integrate in design – for example, through its circular-economy use – policies should in parallel help firms build up incentives to invest and manage intangibles, like design, in a strategic way.

There are some limitations the current paper could not overcome. First, the cross-sectional nature of the data does not allow interpreting obtained results in terms of causation, but only as mere correlation. Although the methodological choices we adopted tried to limit endogeneity issues in the design variable, it has to be acknowledged that directionality may still go in the opposite direction. A panel dataset, not available yet with the kind of specific info we need, would allow to proper treat this bidirectional link. Second, as we already said in the text, environmental regulation is accounted for through a country-sector variable based on environmental protection expenditures. However, no better alternative could be found, and still debated is how to better account for this aspect in the empirical analysis (Mazzanti et al. 2016). The choice of including the full set of interactions between country and sector dummies could mitigate this problem, and results have proven to be robust to this inclusion. Third, although the database chosen is quite rich of information, most of the variables of interest were only available as categorical ones, whereas continuous variables would have allowed a richer analysis to be constructed and thus richer results to be discussed.

Last, but not least, as the Innobarometer does not contain detailed info about the drivers of eco-innovation vs. those of 'standard' innovations, we are unable to inspect the extent to which design could be a differential input between the two. Accordingly, this is a research question, which should await for a more suitable dataset.

Acknowledgments

This research has been in part carried out while Claudia Ghisetti was at the Joint Research Centre of the European Commission. The views expressed are those of the authors and do not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of this publication.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Sandro Montresor http://orcid.org/0000-0002-1195-901X

References

Ai, C., and E. C. Norton. 2003. "Interaction Terms in Logit and Probit Models." *Economics Letters* 80 (1): 123–129. doi:10.1016/S0165-1765(03)00032-6.

Albrizio, S., T. Kozluk, and V. Zipperer. 2017. "Environmental Policies and Productivity Growth: Evidence across Industries and Firms." *Journal of Environmental Economics and Management* 81: 209–226. doi:10.1016/j.jeem.2016.06.002.

Beard, C., and R. Hartmann. 1997. "Naturally Enterprising –Eco-Design, Creative Thinking and the Greening of Business Products." *European Business Review* 97 (5): 237–243. doi:10.1108/09555349710179852.

Bocken, N. M. P., M. Farracho, R. Bosworth, and R. Kemp. 2014. "The Front-End of Eco-Innovation for Eco- Innovative Small and Medium Sized Companies." *Journal of Engineering and Technology Management* 31: 43–57. doi:10.1016/j.jengtecman.2013.10.004.

Boks, C. 2006. "The Soft Side of Ecodesign." *Journal of Cleaner Production* 14 (15): 1346–1356. doi:10.1016/j.jclepro.2005.11.015.

Botta, E., and T. Kozluk (2014). Measuring Environmental Policy Stringency in OECD Countries: A Composite Index Approach. OECD Economic Department Working Papers, (1177), 0_1.

Braungart, M., W. McDonough, and A. Bollinger. 2007. "A Cradle-To-Cradle Design, Creating Healthy Emissions: A Strategy for Eco-Effective Product and System Design." *Journal of Cleaner Production* 15 (13–14): 1337–1348. doi:10.1016/j.jclepro.2006.08.003.

Brunel, C., and A. Levinson. 2016. "Measuring the Stringency of Environmental Regulations." *Review of Environmental Economics and Policy* 10 (1): 47–67. doi:10.1093/reep/rev019.

Byggeth, S., and E. Hochschorner. 2006. "Handling Trade-Offs in Ecodesign Tools for Sustainable Product Development and Procurement." *Journal of Cleaner Production* 14: 1420–1430. doi:10.1016/j.jclepro.2005.03.024.

Carrillo, J., P. Del Río González, and T. Könnölä. 2009. *Eco-Innovation: When Sustainability and Competitiveness Shake Hands*. London: Palgrave Macmillan.

Cerdan, C., C. Gazulla, M. Raugei, E. Martinez, and P. Fullana-i-Palmer. 2009. "Proposal for New Quantitative Eco-Design Indicators: A First Case Study." *Journal of Cleaner Production* 17: 1638–1643. doi:10.1016/j.jclepro.2009.07.010.

Chiburis, R. C. (2010). Score Tests of Normality in Bivariate Probit Models: Comment and Implementation, Working paper, University of Texas at Austin.

Chiburis, R. C., J. Das, and M. Lokshin. 2012. "A Practical Comparison of the Bivariate Probit and Linear IV Estimators." *Economics Letters* 117 (3): 762–766. doi:10.1016/j.econlet.2012.08.037.

Ciriaci, D. 2017. "Intangible Resources: The Relevance of Training for European Firms' Innovative Performance." *Economia Politica* 34 (1): 31–54. doi:10.1007/s40888-016-0049-8.

Cluzel, F., F. Vallet, B. Tyl, G. Bertoluci, and Y. Leroy (2014). Eco-DESIGN Vs. Eco- Innovation: An Industrial Survey. 13th International DESIGN Conference - DESIGN 2014, May 2014, Dubrovnik, Croatia. Proceedings of the 13th International Design Conference - DESIGN 2014, 1501–1510. <hal-01144352>.

Del Río, P., C. Peñasco, and D. Romero-Jordán. 2016. "What Drives Eco-Innovators?: A Critical Review of the Empirical Literature Based on Econometric Methods." *Journal of Cleaner Production* 112: 2158–2170. doi:10.1016/j.jclepro.2015.09.009.

Ellen Macarthur Foundation. 2015. *Delivering the Circular Economy: A Toolkit for Policymakers*. EMF.

Esslinger, H. 2011. "Sustainable Design: Beyond the Innovation-Driven Business Model." *Journal of Product Innovation Management* 28 (3): 401–404. doi:10.1111/jpim.2011.28.issue-3.

European Commission (December 2, 2015), "Closing the Loop - an EU Action Plan for the Circular Economy", COM(2015) 614, Brussels.

European Environmental Bureau. 2015. *Delivering Resource Efficient Products. How Eco Design Can Drive Circular Economy in Europe*. Brussels: EEB.

Gagliardi, L., G. Marin, and C. Miriello. 2016. "The Greener the Better? Job Creation Effects of Environmentally-Friendly Technological Change." *Industrial and Corporate Change, January*. doi:10.1093/icc/dtv054.

Galindo-Rueda, F., and V. Millot (2015). Measuring Design and Its Role in Innovation. OECD Science, Technology and Industry Working Papers, 2015/01, OECD Publishing.

Ghisetti, C., and F. Pontoni. 2015. "Investigating Policy and R&D Effects on Environmental Innovation: A Meta-Analysis." *Ecological Economics* 118: 57–66. doi:10.1016/j.ecolecon.2015.07.009.

Greene, W. H. 2008. *Econometric Analysis*. 6th ed. New Jersey: Pearson Prentice Hall.

Greene, W. H. 2010. "Testing Hypotheses about Interaction Terms in Nonlinear Models." *Economics Letters* 107 (2): 291–296. doi:10.1016/j.econlet.2010.02.014.

Hänsch Beuren, F., M. Gitirana Gomes Ferreira, and P. A. Cauchick Miguel. 2013. "Product-Service Systems: A Literature Review on Integrated Products and Services." *Journal of Cleaner Production* 47: 222–231. doi:10.1016/j.jclepro.2012.12.028.

Hatzichronoglou, T. (1997) Revision of the High-Technology Sector and Product Classification". OECD Science, Technology and Industry Working Papers, No. 1997/02, OECD Publishing, Paris. doi: 10.1787/134337307632

Horbach, J. 2008. "Determinants of Environmental innovation—New Evidence from German Panel Data Sources." *Research Policy* 37 (1): 163–173. doi:10.1016/j.respol.2007.08.006.

Horbach, J., C. Rammer, and K. Rennings. 2012. "Determinants of Eco-Innovations by Type of Environmental impact—The Role of Regulatory Push/Pull, Technology Push and Market Pull." *Ecological Economics* 78: 112–122. doi:10.1016/j.ecolecon.2012.04.005.

Horbach, J., V. Oltra, and J. Belin. 2013. "Determinants and Specificities of Eco-Innovations. An Econometric Analysis for the French and German Industry Based on the Community Innovation Survey." *Industry and Innovation* 20 (6): 523–543. doi:10.1080/13662716.2013.833375.

Johansson, G., and T. Magnusson. 2006. "Organising for Environmental Considerations in Complex Product Development Projects: Implications from Introducing a "Green" Sub-Project." *Journal of Cleaner Production* 14 (15): 1368–1376. doi:10.1016/j.jclepro.2005.11.014.

Johnstone, N., I. Haščič, and D. Popp. 2010. "Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts." *Environmental and Resource Economics* 45 (1): 133–155. doi:10.1007/s10640-009-9309-1.

Karlsson, R., and C. Luttropp. 2006. "EcoDesign: What's Happening? an Overview of the Subject Area of EcoDesign and of the Papers in This Special Issue." *Journal of Cleaner Production* 14: 1291–1298. doi:10.1016/j.jclepro.2005.11.010.

Kemp, R., and P. Pearson (2007). Final Report MEI Project about Measuring Eco-Innovation. http://www.oecd.org/env/consumption-innovation/43960830.pdf

Knight, P., and J. O. Jenkins. 2009. "Adopting and Applying Eco-Design Techniques: A Practitioners Perspective." *Journal of Cleaner Production* 17: 549–558. doi:10.1016/j.jclepro.2008.10.002.

Leoncini, R., A. Marzucchi, S. Montresor, F. Rentocchini, and U. Rizzo (2017)," 'Better Late than Never': The Interplay between Green Technology and Age for Firm Growth", Small Business Economics (forthcoming). doi:10.1007/s11187-017-9939-6

Luttropp, C., and J. Lagerstedt. 2006. "EcoDesign and the Ten Golden Rules: Generic Advice for Merging Environmental Aspects into Product Development." *Journal of Cleaner Production* 14: 1396–1408. doi:10.1016/j.jclepro.2005.11.022.

Maddala, G. S. 1983. *Limited Dependent and Qualitative Variables in Econometrics*. Cambridge: Cambridge University Press.

Mairesse, J., and P. Mohnen, 2010. Using Innovations Surveys for Econometric Analysis, Discussion paper, NBER Working Paper 15857.

Marzucchi, A., and S. Montresor. 2017. "Forms of Knowledge and Eco-Innovation Modes: Evidence from Spanish Manufacturing Firms." *Ecological Economics* 131: 208–221. doi:10.1016/j.ecolecon.2016.08.032.

Mazzanti, M., D. Antonioli, C. Ghisetti, and F. Nicolli (2016). Firm Surveys Relating Environmental Policies, Environmental Performance and Innovation. OECD Environment Working Papers, No. 103, OECD Publishing, Paris.

McAloone, T. C., and N. Bey. 2009. *Environmental Improvement through Product Development: A Guide*. Copenhagen: Danish Environmental Protection Agency.

Mont, O. K. 2002. "Clarifying the Concept of Product–Service System." *Journal of Cleaner Production* 10: 237–245. doi:10.1016/S0959-6526(01)00039-7.

Montresor, S., and A. Vezzani. 2016. "Intangible Investments and Innovation Propensity." *Evidence from the Innobarometer 2013. Industry and Innovation* 23 (4): 331–352.

Montresor, S., and A. Vezzani (2017). Design, Innovation and Performance in European Firms. JRC Working Papers on Corporate R&D and Innovation No 01/2017.

Montresor, S., G. Perani, and A. Vezzani (2014). How Do Companies Perceive Their Intangibles? New Statistical Evidence from the Innobarometer 2013. Technical report. Institute of Prospective Technological Studies (IPTS), European Commission. Luxembourg: Publications Office of the European Union.

Mourifié, I., and R. Méango. 2014. "A Note on the Identification in Two Equations Probit Model with Dummy Endogenous Regressor." *Economics Letters* 125 (3): 360–363. doi:10.1016/j.econlet.2014.10.006.

Mulder, K. F. 2007. "Innovation for Sustainable Development: From Environmental Design to Transition Management." *Sustainability Science* 2 (2): 253–263. doi:10.1007/s11625-007-0036-7.

Murphy, A. 2007. "Score Tests of Normality in Bivariate Probit Models." *Economics Letters* 95 (3): 374–379. doi:10.1016/j.econlet.2006.11.010.

Noailly, J., and R. Smeets. 2015. "Directing Technical Change from Fossil-Fuel to Renewable Energy Innovation: An Application Using Firm-Level Patent Data." *Journal of Environmental Economics and Management* 72: 15–37. doi:10.1016/j.jeem.2015.03.004.

Norton, E. C., H. Wang, and C. Ai. 2004. "Computing Interaction Effects and Standard Errors in Logit and Probit Models." *Stata Journal* 4: 154–167.

Popp, D. 2002. "Induced Innovation and Energy Prices." *American Economic Review* 92 (1): 160–180. doi:10.1257/000282802760015658.

Popp, D. 2006. "International Innovation and Diffusion of Air Pollution Control Technologies: The Effects of NOX and SO2 Regulation in the US, Japan, and Germany." *Journal of Environmental Economics and Management* 51 (1): 46–71. doi:10.1016/j.jeem.2005.04.006.

Reim, W., V. Parida, and D. Ortqvist. 2015. "Product Service Systems (PSS) Business Models and Tactics: A Systematic Literature Review." *Journal of Cleaner Production* 97: 61–75. doi:10.1016/j.jclepro.2014.07.003.

Rennings, K. 2000. "Redefining Innovation—Eco-Innovation Research and the Contribution from Ecological Economics." *Ecological Economics* 32 (2): 319–332. doi:10.1016/S0921-8009(99)00112-3.

Ryan, C. 2003. "Learning from a Decade (Or So) of Eco-Design Experience Part I, ." *Journal of Industrial Ecology* 7 (2): 10–12. doi:10.1162/108819803322564316.

Santolaria, M., J. Oliver-Solà, C. M. Gasol, T. Morales-Pinzón, and J. Rieradevall. 2011. "Eco-Design in Innovation Driven Companies: Perception, Predictions and the Main Drivers of Integration. The Spanish Example." *Journal of Cleaner Production* 19: 1315–1323. doi:10.1016/j.jclepro.2011.03.009.

Tether, B. S. 2006. *Design in Innovation: Coming Out from the Shadow of R&D: An Analysis of the UK Innovation Survey of 2005*. Manchester, UK: Manchester Business School.

Tingström, J., L. Swanström, and R. Karlsson. 2006. "Sustainability Management in Product Development Projects - the ABB Experience." *Journal of Cleaner Production* 14 (15): 1377–1385. doi:10.1016/j.jclepro.2005.11.027.

Triguero, A., L. Moreno-Mondéjar, and M. A. Davia. 2013. "Drivers of Different Types of Eco-Innovation in European SMEs." *Ecological Economics* 92: 25–33. doi:10.1016/j.ecolecon.2013.04.009.

Tukker, A. 2004. "Eight Types of Producte-Service System: Eight Ways to Sustainability? Experiences from SusProNet." *Business Strategy and the Environment* 13 (4): 246–260. doi:10.1002/bse.414.

Tukker, A., P. Eder, M. Charter, E. Haag, A. Vercalsteren, and T. Wiedmann. 2001. "Eco-Design: The State of Implementation in Europe. Conclusions of a State of the Art Study for IPTS." *The Journal of Sustainable Product Design* 1: 147–161. doi:10.1023/A:1020564820675.

Tukker, A., and U. Tischner. 2006. *New Business for Old EuroperProduct Services, Sustainability and Competitiveness*. Sheffield, UK: Greenleaf Publishing Ltd.; 2006.

Vallet, F., B. Eynard, D. Millet, S. G. Mahut, B. Tyl, and G. Bertoluci. 2013. "Using Eco-Design Tools: An Overview of Experts' Practices." *Design Studies* 34 (3): 345–377. doi:10.1016/j.destud.2012.10.001.

van Nes, N., and J. Cramer. 2006. "Product Lifetime Optimization: A Challenging Strategy Towards More Sustainable Consumption Patterns." *Journal of Cleaner Production* 14 (15–16): 1307–1318. doi:10.1016/j.jclepro.2005.04.006.

Vezzoli, C., and D. Sciama. 2006. "Life Cycle Design: From General Methods to Product Type Specific Guidelines and Checklists: A Method Adopted to Develop a Set of Guidelines/Checklist Handbook for the Eco-Efficient Design of NECTA Vending Machines." *Journal of Cleaner Production* 14: 1319–1325. doi:10.1016/j.jclepro.2005.11.011.

Von Hippel, E. 1998. "Economics of Product Development by Users: The Impact of "Sticky" Local Information." *Management Science* 44 (5): 629–644. doi:10.1287/mnsc.44.5.629.

Vona, F., G. Marin, D. Consoli, and D. Popp (2015). Green Skills. National Bureau of Economic Research Working paper (No. w21116).

Walsh, V., R. Roy, M. Bruce, and S. Potter. 1992. *Winning by Design: Technology, Product Design and International Competitiveness*. Oxford, UK: Blackwell Publishers.

Wilde, J. 2000. "Identification of Multiple Equation Probit Models with Endogenous Dummy Regressors." *Economics Letters* 69 (3): 309–312. doi:10.1016/S0165-1765(00)00320-7.

Yang, C. J., and J. L. Chen. 2011. "Accelerating Preliminary Eco-Innovation Design for Products that Integrates Case-Based Reasoning and TRIZ Method." *Journal of Cleaner Production* 19: 998–1006. doi:10.1016/j.jclepro.2011.01.014.

Zelner, B. A. 2009. "Using Simulation to Interpret Results from Logit, Probit, and Other Nonlinear Models." *Strategic Management Journal* 30 (12): 1335–1348. doi:10.1002/smj.v30:12.

Ziegler, A. 2013. "Disentangling Technological Innovations: A Micro-Econometric Analysis of Their Determinants." *Journal of Environmental Planning and Management* 58 (2): 315–335. doi:10.1080/09640568.2013.855180.

Appendix

Table A1. Eco-innovation and design: Probit estimated coefficients with *DESIGN_inv* = 1 for any non-nil percentage of turnover invested in design.

	(1)	(2)	(3)
DESIGN_inv	0.2402***	0.2370***	0.2311***
	(0.0461)	(0.0462)	(0.0494)
Lsize	0.1178***	0.1234***	0.1337***
	(0.0151)	(0.0152)	(0.0161)
RD	0.1618***	0.1504***	0.1944***
	(0.0463)	(0.0465)	(0.0489)
ENVREGL	0.0008	0.0008	
	(0.0013)	(0.0013)	
YOUNG	−0.0361	−0.0393	−0.0610
	(0.0777)	(0.0776)	(0.0818)
INTERNATIONAL_sales	0.0011*	0.0010	0.0005
	(0.0006)	(0.0006)	(0.0007)
GROUP	0.0065	0.0032	−0.0025
	(0.0485)	(0.0485)	(0.0519)
HIGHINNO		0.2868***	0.3399***
		(0.0684)	(0.0726)
Constant	−0.9772***	−0184***	−0.8333***
	(0.1085)	(0.1095)	(0.2280)
N	4465	4465	4400
pseudo R^2	0.0552	0.0581	0.1015

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Although not reported, 27 country dummies and 7 sector dummies (CA, CB, CC, CD-CG, CH, CI-CL, CM in Nace Rev 2) are included in Columns (1)-(3). Column (3), instead, includes the full set of interactions between 27 country and 7 sector dummies, by excluding ENVREGL which was constructed at the country-sector level.

Table A2. Eco-innovation and design: Bivariate probit estimated coefficients with *DESIGN_inv* = 1 for any non-nil percentage of turnover invested in design.

Step 2: EI equation	(1)	(2)	(3)
DESIGN_inv	0.3764**	0.3808***	0.6458***
	(0.1585)	(0.1311)	(0.2027)
Lsize	0.1279***	0.1228***	0.1304***
	(0.0134)	(0.0158)	(0.0198)
RD	0.1633***	0.1452***	0.1706**
	(0.0488)	(0.0443)	(0.0698)
YOUNG	−0.0385	−0.0411	−0.0659
	(0.0734)	(0.0811)	(0.0964)
ENVREGL	0.0009	0.0008	
	(0.0014)	(0.0012)	
INTERNATIONAL_sales		0.0009	0.0001
		(0.0007)	(0.0008)
GROUP		0.0027	−0.0049
		(0.0436)	(0.0460)
HIGHINNO		0.2779***	0.3078***
		(0.0642)	(0.0718)
Constant	−1.0406***	−1.0893***	−1.0304***
	(0.1429)	(0.1164)	(0.2683)
Step 1: Design investment equation			
DESIGN_NOT_USED	−0.9429***	−0.9411***	−0.8968***
	(0.0515)	(0.0434)	(0.0680)
MKT_TESTING	0.2935***	0.2848***	0.2738***
	(0.0634)	(0.0624)	(0.0507)
INTERNATIONAL_sales		0.0031***	0.0030***
		(0.0007)	(0.0006)
HIGHINNO		0.1980***	0.1915***
		(0.0706)	(0.0622)
TURN GROWTH > 25%			0.0832
			(0.0834)
TURN GROWTH 5% to 25%			0.2068***
			(0.0526)
TURN LOST 5% to 25%			0.0449
			(0.0627)
TURN LOST > 25%			−0.1240
			(0.0781)
WEAK_DISTR			0.2161***
			(0.0462)
Constant	0.3542***	0.2201*	0.0911
	(0.0936)	(0.1125)	(0.0936)
Rho	−0.0886	−0.0942	−0.2813**
	(0.0880)	(0.0816)	(0.1295)
N	4465	4465	4465
Average marginal effect of DESIGN_inv on EI	0.0826	0.0802	0.0602
Wald test of rho = 0 Chi_2	1.00	1.13	8.85
Wald test of rho = 0 p> Chi_2	0.31	0.28	0.00

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Although not reported, 27 country dummies and 7 sector dummies (CA, CB, CC, CD-CG, CH, CI-CL, CM in Nace Rev 2) are included in Columns (1)-(3). Column (3), instead, includes the full set of interactions between 27 country and 7 sector dummies, by excluding ENVREGL which was constructed at the country-sector level.

Table A3. Distribution of sample firms by product and process eco-innovators.

	Product Innovation = 0	Product Innovation = 1	Tot
Process Innovation = 0	*1178*	*365*	*1543*
Process Innovation = 1	*1720*	*1202*	*2922*
Tot	*2898*	*1567*	*4465*