Sustainability-oriented Capabilities for Eco-Innovation: Meeting the Regulatory, Technology and Market Demands

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ABSTRACT

Despite consensus in the literature that *regulation*, *technology-push* and *market-pull* drive eco-innovation (EI), evidence remains limited on the diverse firm capabilities needed to boost EI. Building on the natural-resource-based-view (NRBV) of the firm and the EI literature, this paper posits that firms need to renew and realign their capabilities, and ultimately develop distinctive *sustainability-oriented capabilities,* in order to meet the rapidly changing regulatory, technology, and market demands. Results of the analysis, based on a survey of UK firms, reveal that eco-innovations are more likely to arise when firms: (a) build capabilities on *voluntary self-regulation* (i.e. executive driven EMS and CSR) because such organisational capabilities allow them to address increasing regulatory pressures; (b) invest in *environmental research and development* (i.e. eco-R&D)- instead of generic research and development- because it provides them with the relevant and specific technological capabilities to tackle technology shifts towards sustainability; and (c) develop capabilities in *green market sensing* as such capabilities allow them to address green consumption needs.

Keywords: eco-innovation; sustainability-oriented capabilities; voluntary self-regulation; EMS; CSR; environmental research and development

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Introduction

Eco-innovations (EIs) have risen in the strategic agendas of companies due to growing pressures to reduce the environmental impact of the industry. Governments make environmental regulations more stringent to meet environmental targets and introduce various incentives to encourage more environmentally friendly corporate behaviour (Demirel et al., 2018; del Río et al., 2015). Besides regulatory demands and government incentives, the increasing public pressure demanding environmentally friendly practices compels companies to introduce EI in the forms of substituting renewable inputs, redesigning products, services and packaging to reduce waste, and reforming management systems to support a more environmentally friendly corporate infrastructure (Cronin et al., 2010).

EI refers to radical or incremental innovations in products, processes or organizations with reduced environmental impact and it is argued to simultaneously reduce pollution and increase firm competitiveness (Porter & Van Der Linde, 1995; Horbach, 2008; Costantini & Mazzanti, 2012; Bönte & Dienes, 2013; Zubeltzu-Jaka et al., 2017). A growing number of companies view the adoption of EI as an effective route to manage regulatory risks, reduce costs and improve market positioning. A recent report from Climate Disclosure Board (2018) reveals the growing relevance of environmental issues and EI for executive company boards in 14 countries. For instance, following a risk audit in 2011, Microsoft decided that regulatory pressures and price volatility of energy created high enough risk exposures that required to be addressed at the executive level among the 'C-suite issues' and adopted multiple innovations to increase energy efficiency while ensuring 50% of their energy use comes from renewables by 2018 (Winston et al., 2017).

Despite consensus in prior literature that regulatory stimulus, technology-push, and market-pull drive EI (Aragon-Correa & Leyva-de la Hiz, 2016; del Río et al., 2015; Demirel & Kesidou 2011), little is known about the specific [internal] capabilities firms need in order to develop the EI to tackle these stimuli. This paper builds on the *natural-resource-based-view* (NRBV) of the firm (Hart, 1995) and investigates the sustainability-oriented capabilities which present as prerequisites for EI (Dangelico et al., 2017). Internal capabilities are the outcome of bundles of distinct resources - such as basic skills, routines, and learning – that must be in place before companies can develop cutting-edge EI at the required rate (Darnall, 2006; Hart, 1995; Christmann, 2000; Doran & Ryan, 2016). Findings of the paper show that in the face of diverse external pressures, firms are attempting to renew their capabilities in order to meet the increasing need and demand for EI. However, not all resources and capabilities are relevant for EI unless they are sustainability-oriented. Recent studies empirically investigate the importance of various sustainability-oriented capabilities for environmental strategies (Tsai & Liao, 2017; Albort-Morant et al., 2016; Leonidou et al, 2015; Russo, 2009; Berchicci, et al., 2012; Hofmann et. al., 2012). We contribute to this growing stream of strategy literature [1] by exploring the research question: which sustainability-oriented capabilities drive EI?

The following section reviews the literature around the conceptual framework and research hypotheses. Subsequently, we present the details of data collection, descriptive statistics, and the econometric model. We proceed with the data analysis, the discussion of results, and conclusions.

Theory and Hypotheses

Eco-innovation (EI)

Global warming, energy scarcity along with increases in pollution bring environmental issues high up in government agendas leading to progressively more stringent environmental regulations (Demirel et al., 2018). A corresponding change in demand patterns exists in the form of environmental consumption, requiring firms to adapt their products and services (Young et al., 2010). In sum, a rapidly changing environment puts significant pressure on firms to consider which organizational processes have to be transformed to develop new capabilities to facilitate EI.

EI [2] can be defined as *"all forms of innovations that reduce environmental impact … throughout the lifecycle of related activities"* (OECD, 2011, p.29). OECD (2011) emphasizes that EIs do not necessarily originate from the environmental sector; instead manufacturing

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[1] Prior studies point to the importance of technological, marketing, external integrative and internal integrative capabilities (Dangelico et al., 2017) as well inter-organizational and intra-organisational factors (Melander, 2018) that drive EI.

[2] "Eco-innovations", "green innovations", "environmental innovations", and "sustainable innovations" are terms used interchangeably in the literature to refer to innovations with reduced environmental impact. Yet, there are differences between these terms as "green innovations" and "environmental innovations" focus predominantly on limiting the impact upon the environment. By contrast, the term "eco-innovations" conceptualises that an innovation would simultaneously reduce environmental impact and increase a firm's competitiveness. Finally, "sustainable innovations" takes into consideration besides the positive impact of an innovation upon the environment, a positive societal impact (Zubeltzu‐Jaka et al., 2017).

and service firms are increasingly taking part in the generation of environmental innovations. Moreover, the nature of EI is not always technological but extends to broader organizational innovations within the company and across the supply chain (OECD, 2009). A key feature of EI concerns its dual externality, whereby it enhances societal welfare by simultaneously reducing negative environmental externalities (e.g. emission control) and by increasing positive knowledge externalities (e.g. adoption/diffusion of novel green technologies by other firms) (De Marchi, 2012; Ghisetti & Pontoni, 2015; Zubeltzu-Jaka et al., 2017). In this paper, we focus on EI in products/services (e.g. eco-buildings, electric cars, eco-holidays, car sharing) and processes (e.g. re-planning energy and water use to minimize waste) as they are the most visible types of EI.

Sustainability-oriented Capabilities

Prior to the recent growth in EI scholarship in the economics of innovation literature, the strategic management literature had emphasised the *natural-resource-based-view* (NRBV) of the firm (Hart, 1995), which posits that firms need to realign their capabilities and respective resources to generate new sources of competitive advantage under environmental constraints. This view builds on the resource-based view of the firm (RBV)[3] and the dynamic capabilities literature[4], which propose that firm-specific capabilities are essential for the survival and success of companies and need to be constantly renewed to respond to the shifting business environment. Dynamic capabilities (Teece, 2007) and their micro-foundations (i.e. routines) (Winter, 2003) are the roots of competitive advantage and the sources of innovation.

Recent studies in the EI literature build on the insights from dynamic capabilities literature to investigate the implications of firm capabilities for firms' environmental actions. Dangelico et al. (2017) define firms' *sustainability oriented dynamic capabilities* as their "ability to integrate, build and reconfigure competences and resources to embed environmental sustainability into new product development to respond to changes in the market" (p.490). In a similar vein, Jiang et al. (2018) view a firm's green orientation as part of the dynamic capabilities that can position the firm strongly in markets. Hofmann et al. (2012) conceptualise dynamic capabilities that help firms to become greener under three key

[3] The resource-based view states that competitive advantage derives from unique, imperfectly mobile and difficult to imitate resources and capabilities (Peteraf, 1993; Barney, 1991).
[4] In their seminal paper, Teece and Pisano (1994) defined dynamic capabilities as the ability of the management for *"appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences toward changing environment"* (p.538).

constructs; advanced technology, inter-firm relations/collaborations and innovation capacity. Pacheco et al. (2018) further emphasize that any knowledge-based capability should be specific to the environmental domain in order to facilitate successful EI that can deliver corporate value. Kabongo and Boiral (2017) review the NRBV literature and outline a list of organizational capabilities covered in various studies as important building blocks for sustainability-oriented capabilities. These include quality management, continuous improvement, continuous innovation, stakeholder integration, collaboration, higher order learning, and adoption of advanced technologies (see p.959 for full details).

Sustainability-oriented Capabilities for Eco-Innovation: A conceptual framework

In this section, we disentangle firm capabilities to investigate which are most important for EI and why. Our departure point is prior research on EI in the economics of innovation and ecological economics literatures. Growing consensus there suggests that (1) *regulation* (Bossle et al, 2016; Kunapatarawong & Martínez-Ros, 2016; Kesidou & Demirel, 2012), (2) *technology-push* (Ghisetti & Pontoni, 2015; Demirel and Kesidou, 2011), and (3) *market-pull* (Lin et al, 2013; Horbach, 2008; Rehfeld et al., 2007, Jové-Llopis & Segarra-Blasco, 2018) drive firms to adopt and/or develop EI. Firstly, environmental *regulation* is progressively tightening over time besides the numerous economic incentives provided for investing in EI. Secondly, renewable energy and environmental *technologies* offer opportunities for firms to green their production processes and their products. Finally, addressing customer calls for green products -sourced through global green supply chains- has become necessary to meet green *market* demands.

Yet, this literature has partly overlooked how firms could respond to these stimuli using their internal capabilities. In other words, what are the respective capabilities that firms need in order to respond to the regulatory, technology-push and market pull stimuli? Strategic management literature has provided answers to this question by underlining the importance of sustainability-oriented capabilities in creating competitive advantage. For instance, Melander et al (2018) examine a range of internal and external organizational capabilities in successful green product innovations. They identify capabilities specific to the environmental domain to be important for green product innovations. Among these, the authors point to the environmental management capabilities (including dedicated environmental R&D), a green corporate culture (including strong sustainability focus at the corporation level) and training for environmental matters as important internal organizational capabilities (Melander, 2018). Kabongo and Boiral (2017) identify technological innovations, control of residual flows, human resource capabilities (including hiring and training), green management capabilities (including green marketing, interconnectedness within the company), higher order learning and strategic growth as key organizational capabilities that drive eco-efficiency. Ko and Liu (2016) and Pacheco et al. (2018) posit that organizational capabilities such as R&D and marketing capabilities are higher order capabilities that enable firms to benefit from their green strategies. Lee and Klassen (2016) consider the role of organizational learning and lean production capabilities as important drivers of carbon management practices. Whilst, these insights are useful, it is yet not fully clear how distinct capabilities map into firms' efforts to address regulatory pressures, technology push and market pull.

Hereby, we make a synthesis of these two separate bodies of literature by developing a conceptual framework that elucidates the distinct sustainability-oriented capabilities that allow firms to effectively address *regulatory*, *technological*, and *market* demands respectively, and in turn, increase the likelihood for a firm's strategic decision to invest in EI (see Figure 1). Firstly, we argue that firms are able to tackle regulatory pressures by adopting *voluntary self-regulations* such as *environmental management systems* (EMS) and *corporate social responsibility* (CSR) frameworks. This is because firms that adopt EMS are able to build unique environmental management capabilities that allow them to address regulatory pressures (Demirel et al, 2018). Also, firms are only able to gain a competitive advantage when they build internal capabilities that align the implementation of CSR with a clear communication strategy with external stakeholders (Hawn & Ioannou, 2016). Secondly, we contend that firms could respond effectively to technological shifts towards sustainability by building *technological capabilities*, not in in generic research and development (R&D), but instead in *environmental R&D*. This is because generic R&D is often related to the core business of the firm, which is usually associated with old carbon-intensive technologies. Instead, in order to bring about EIs in manufacturing and delivery, firms should invest in *environmental R&D* that can be considered peripheral to the firm's core technologies (March, 1991). Finally, we posit that customer and supplier pressures should be dealt carefully by building capabilities in *green market sensing capabilities* so as to capture customers' willingness to pay for green products and the potential markets of product EIs.

[FIGURE 1 ABOUT HERE]

Regulation: Environmental Self-regulation Capabilities

An Environmental management system (EMS) is a mode of voluntary environmental self-regulation, which is used to correct problems arising from information asymmetries, to regulate global supply chains, and to respond to increasing regulatory pressures (Potoski & Prakash, 2012). The EI literature suggests that EMS generally prove to be effective in strengthening environmental management capabilities and environmental performance, through facilitating environmental target setting and stimulating information flows (Arimura et al., 2008; Rennings et al., 2006). Studies find that these capabilities are stronger and more effective in cases of complete EMS implementation, as EMS matures over time and if EMS is implemented as a strategic/executive issue (Boiral, 2007; Heras-Saizarbitoria et al., 2016; Mazzi et al., 2016; Melynk et al., 2003; Russo, 2009; Thomas & Simerly, 1994; Shaukat et al., 2016). Similar to the case of EMS, CSR literature argues that implementation of CSR allows companies to develop powerful ethical management capabilities, including environmental management, that can positively affect firm's environmental and economic performance (Hawn & Ioannou, 2016). We posit that firms that have implemented EMS and CSR are more likely to develop the environmental management capabilities that can facilitate EI.

Hypothesis 1: Environmental self-regulation capabilities embodied in EMS positively affect firm's decision to introduce EI.

Hypothesis 2: Environmental self-regulation capabilities embodied in CSR positively affect firm's decision to introduce EI.

Technology Push: Environmental Technology Capabilities

Undertaking research and development (R&D) is essential to build the technological capabilities required to innovate and to ensure the presence of absorptive capacity that can fuel further learning from external sources of information (Wiliander, 2016; Freeman & Soete, 1997; Pacheco et al., 2018).

Majority of the EI literature finds that firms' generic R&D investments (Ghisetti et al., 2015; Ghisetti & Pontoni, 2015; Horbach, 2016; Constantini et al., 2015; Jové-Llopis & Segarra-Blasco, 2018) and the R&D investments specifically dedicated to environmental technologies (i.e. eco-R&D) (Costa-Campi et al., 2017; Demirel and Kesidou, 2011; Lee & Min, 2015; Melander et al., 2018) positively affect their ability to introduce EI. Generic R&D and eco-R&D can be framed in the context of local vs. distant search, whereby the former refers to R&D activities that are closely related to the core business of the firm while the latter refers to the more outward-looking 'exploration' activities (March and Simon, 1958). While local search is essential for developing and commercializing emerging ideas, it is important for firms to balance their local search with distant search in order to avoid inertia and learning myopia that can lead to technological lock-ins (Levinthal & March, 1993; Lee et al., 2003). EI often represents a significant diversion from business as usual and can be considered peripheral and in the domain of ‘distant search’ for many firms (March & Simon, 1958). Firms, which do not divert some of their R&D budgets into environmental technologies, may risk being locked into polluting technologies after failing to develop their EI-specific technological capabilities. To the best of our knowledge, the only study that compares the impact of generic R&D and eco-R&D on firms’ eco-innovation potential is Lee and Min (2015) who note that only R&D investments dedicated to green technologies build up the technological capabilities required to reduce the environmental impact of firms through EI. Authors add that an increase in generic R&D can indeed attenuate the positive effects of environmental R&D investments. Based on these insights we expect generic and eco-R&D to facilitate the development of technological environmental capabilities that lead to EI.

Hypothesis 3: Technological capabilities embodied in generic R&D positively affect firm’s decision to introduce EI.

Hypothesis 4: Technological capabilities embodied in Eco-R&D positively affect firm’s decision to introduce EI.

Market Pull: Environmental Market Sensing Capabilities

Market sensing capabilities are at least as important as technological capabilities since awareness of changes in demand is crucial for business success (De Luca et al., 2010). Day (1994) argues that ‘market sensing’ is a key distinctive organizational capability that allows firms to sense and react to events in their markets and also to forecast future trends while Narver et al. (2004) highlight the role of market sensing capabilities in identifying market opportunities that consumers are not aware of but would potentially value.

Market sensing capabilities are also highlighted as crucial for the development of EI (Dangelico and Vocalelli, 2017; Dangelico, 2015; Ko and Liu, 2016) and insufficiencies in understanding market signals and trends are known to be behind unsuccessful EI that are not well received by customers (Ottman et al., 2006). Market research helps firms generate market intelligence through collecting and processing information on customer and competitor orientations, and is crucial for building strong market sensing capabilities that act as a sustainable advantage (Heusinkveld et al., 2009). The market-orientation literature documents a close link between the strength of a firm's market sensing capabilities and its innovations. According to Heusinkveld et al. (2009) *"a good nose for new marketable products"* is the first step for new concept development and innovations (p.514). Likewise, empirical studies point to strong associations between firms' market sensing capabilities and EI (Dangelico, 2015; Tsai et al, 2012). Therefore, we expect firms' market research sensing capabilities to positively affect EI.

Hypothesis 5: Environmental market sensing capabilities positively affect firm's decision to introduce EI.

Data and Methodology

Primary data was collected through a survey of UK manufacturing firms between June-November 2010. The FAME database (compiled by the Bureau van Dijk) was used for sampling the firms. Stratified random sampling techniques was applied, allowing for a representative presentation of small, medium and large firms from all manufacturing sectors. In total, 1,695 active UK firms from 35 manufacturing sectors were contacted and after two mail shots and follow-up calls, 169 responses were returned leading to a response rate of roughly 10%.

Similarly sized cross-sectional survey-based datasets are used in the EI literature to investigate various matters around the drivers and outcomes of EI as well as sustainability-oriented capabilities (e.g. Amankwah-Amoa et al., 2018; Dangelico et al, 2017; Lee and Klassen, 2016 among others). A growing number of quantitative studies resort to self-designed firm surveys to capture in-depth information about firms' environmental activities since this information is limited in most community innovation surveys. The survey in this study used a structured questionnaire based to a certain degree on the Community Innovation Survey (BIS, 2012) but also included detailed questions on the environmental activities of the firms. The questionnaire asked firms about certain company characteristics such as sales and employment, the different types of eco-innovations they have undertaken in the last 3 years and other activities that helped identify different dimensions of firms' sustainability-oriented capabilities.

The two dependent variables used individually in our analysis are (a) Product Eco-Innovation (*Product EI*) and (b) Process Eco-Innovation (*Process EI*) and these variables are summarized in Table 1. The descriptive statistics indicate that 43% of the firms have conducted product EI, whilst around 45% of the firms have conducted process EI. These percentages are slightly higher compared to the product and process innovation rates reported in UK's Community Innovation Survey. To rule out the possibility of a potential sample bias towards larger firms which tend to be more innovative on average (Hughes, 2001), we conducted a non-response analysis based on independent group t-tests comparing the firm size indicators (the number of employees (*SIZE*) and turnover (*SALES*)) between the responding and non-responding firms. The results reported in Appendix A confirm that the average firm size in the sample of responding firms is not significantly different from the average sample of non-responding firms[5]. Hence, we are assured the high innovativeness rates among firms in our sample are potentially attributable to characteristics of environmental innovations and firm characteristics other than size.

[TABLE 1 ABOUT HERE]

Table 2 reports the descriptive statistics for the proxies of sustainability-oriented capabilities used in the analysis. To capture *Environmental Self-regulation Capabilities,* we use a range of proxies, namely, dummy variables that indicate whether a company has implemented EMS through the appointment of an administrative officer (*Admin_EMS) and/or* an executive manager (*Exec_EMS*) and the years of experience in using EMS (*Exper_EMS).* Additionally, we include a dummy variable that captures whether corporate social responsibility policies (*CSR*) have played a role in firms' decision to invest into EI.

We measure *Environmental Technology Capabilities* with two variables, namely *R&D* and *EcoR&D,* which respectively reflect whether firms have a budget item dedicated to R&D and environmental R&D activities. These variables directly capture the generic and environmentally specific technology capabilities.

As a proxy for *Environmental Market Sensing Capabilities*, we use a binary variable *Market Research,* which indicates whether firms have undertaken market research in relation to environmental products or processes.

[TABLE 2 ABOUT HERE]

Additional to capability variables, we control for the role of government regulation (*Regulation*), firms' focus on reducing material costs *(Materials),* firm's training activities on environmental matters (*Train*), whether they consider consumer demand (*Demand*) to be an important factor in decision making related to environmental matters, focus on international markets *(International),* firm size *(Size),* sales growth *(Growth)* as well as the industry pollution intensity factors *(Low/Medium/High)*. The *Regulation*, *Materials, Train, Demand*,

[5] All firms surveyed and those firms that chose not to respond were used in constructing the sample of non-responding firms. Firm size data for non-responding firms was attained from the FAME database.

and *International* variables are based on companies' views of how important each factor is perceived within the company's overall vision for environmental activities. Firm *size* is measured via the logarithm of number of employees and firm *growth* is measured by calculating the growth of sales. Finally, we control for inter-industry differences in pollution intensities by using dummies to indicate *MEDIUM* and *HIGH* pollution industries [6]. Definitions and descriptive statistics for all control variables are provided in Table 3.

[TABLE 3 ABOUT HERE]

Since both dependent variables are binary in nature, we use a Probit binary response model[7] where the dependent variables are (a) *Product EI* and (b) *Process EI*, and the independent variables are the abovementioned proxies for (1) environmental self-regulation capabilities, (2) environmental technology capabilities, (3) environmental market sensing capabilities along with the discussed control variables.

Results

The results of Probit regressions are presented in Table 4. The reported estimates are average partial effects, which can be easily interpreted in terms of probabilities. Models 1 and 2 report the results of product EI, whilst models 3 and 4 show the results of process EI.

H1 postulates that environmental self-regulation capabilities embodied in EMS positively affect firm's decision to introduce EI. This hypothesis is partially supported by our results. Specifically, Models 2 and 4 indicate that the variable Exec_EMS increases the probability of both product EI (β=1.288, $p<0.05$) and process EI (β=1.106, $p<0.05$)[8]. Model 2 points out that the variable Exper_EMS increases the probability of product EI (β=0.115, $p<0.1$). Yet, Model 2 indicates that the variable Admin_EMS reduces the probability of

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[6] The set of industries covered in the sample correspond to the UK SIC 2003 codes 10, 11, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 40 and 41. We have classified these industries in three groups with respect to their pollution intensity: LOW, MEDIUM and HIGH Emission. This classification is based on greenhouse gas (GHG) emissions data for 93 UK Economic Sectors between 1990 and 2008 provided by Department for Environment, Food and Rural Affairs. We have taken an average for the GHG emissions for each sector in the UK across the years and ranked these values in ascending order. In what follows, the industries classified as LOW emission are those that are at the lowest quartile of the UK pollution intensity, those classified as MEDIUM emission are those that are within the 2nd and 3rd quartiles of the range and finally, the industries classified as HIGH emission are those in the top quartile of the UK pollution intensity.

[7] A Bivariate Probit model has also been conducted for robustness reasons. Whilst the results are consistent with the Probit models presented in the paper, the Wald test of the exogeneity assumption suggests that two separate models should be used. The Wald test that examines the null hypothesis that the dependent variables are independent (i.e. the error terms are not correlated) cannot be rejected [rho=0: chi2(1) = .011583; Prob > chi2 = 0.9143].

[8] Note that Admin_EMS and Exec_EMS are used in comparison to the base of no EMS.

product EI (β=-0.811, p<0.1). In sum, our results suggest that self-regulation capabilities embodied in EMS boost product or process EI only when the firm makes a deep and long term commitment to EI at the highest/executive levels. H2 contends that environmental self-regulation capabilities embodied in CSR positively affect firm's decision to introduce EI. This hypothesis is supported solely in the case of product EI. Specifically, the variable CSR increases the probability of product EI (β=1.676, p<0.1).

H3 suggests that technological capabilities embodied in generic R&D positively affect firm's decision to introduce EI. Our results do not support this hypothesis, as none of the coefficients of R&D is statistically significant. H4 proposes that technological capabilities embodied in Eco-R&D positively affect firm's decision to introduce EI. Our results in Models 2 and 4 support this hypothesis as they indicate that Eco-R&D stimulates both product EI (β=1.654, p<0.05) and process EI (β=1.368, p<0.1). Finally, H5 suggests that environmental market sensing capabilities positively affect firm's decision to introduce EI. This hypothesis is valid only in the case of product EI as Model 2 shows that the variable Market search increases the probability of product EI (β=1.829, p<0.01). Among the control variables, the demand variable is found to have the most significant impact on product EI while the materials reduction variable is found to have the most significant impact on process EI.

[TABLE 4 ABOUT HERE]

Discussion and Conclusions

Prior literature on eco-innovation stresses that understanding the mechanisms that drive EI is pivotal for generating managerial and policy strategies that can pave the way to a greener economy (OECD, 2011). The growing consensus in the literature is that *regulation*, *technology-push* and *market-pull* drive eco-innovation (Aragon-Correa & Leyva-de la Hiz, 2016; del Río et al., 2015; Demirel & Kesidou 2011). However, we still lack sufficient understanding of the specific internal capabilities firms need in order to develop EI and tackle these external stimuli.

This paper addresses these caveats in the literature by examining the internal capabilities that must be in place before companies can develop cutting-edge product or process EIs. Employing a survey-based firm-level data from the UK, the results of this paper offer new empirical evidence, which shows that not all resources and capabilities are relevant to tackle the rapidly changing regulatory, technology, and market demands, unless they are *sustainability-oriented.* We argue that eco-innovations are more likely to arise when firms build capabilities on *voluntary self-regulation,* invest in *environmental research and development,* and develop capabilities in *green market sensing*.

Our findings contribute to the literature in a number of ways. Firstly, regarding the importance of environmental self-regulation capabilities for eco-innovation, our results offer critical insights suggesting that EMS implementation does not significantly boost product or process EI *unless* it is undertaken with a deep commitment at the highest/executive levels in the company. Confirming the findings of Thomas and Simerly (1994) and Shaukat et al. (2016), this study finds that executive level commitment to environmental management (i.e. through assignment of an executive officer to take charge of EMS) is essential for building strong sustainability-oriented environmental capabilities. The ambivalence regarding the potential effectiveness of EMS is documented in the literature (Könnöla & Unruh, 2007; Darnall, 2006). It is argued that adoption of EMS on its own is not sufficient for strengthening organizational capabilities; rather the quality of implementation matters the most, and this differs highly across organisations. The literature notes suboptimal and incomplete implementations of EMS due to reasons such as lack of specialist staff, lack of training, and inadequate technical knowledge and skills (Mazzi et al., 2016). In such cases, companies fail to develop strong organisational environmental capabilities despite implementing EMS. Likewise, superficial and unauthentic implementation of EMS solely for the purpose of green signalling (i.e. green-washing) fails to develop strong sustainability-oriented capabilities (Boiral, 2007). Various studies also argue that EMS needs to mature over time in order to provide firms with strong sustainability-oriented capabilities (Heras-Saizarbitoria et al., 2016; Melynk et al., 2003; Russo, 2009).

Secondly, with regards to the importance of technological capabilities for eco-innovation, our results offer novel evidence that points out that generic R&D efforts *do not* affect EI. Instead, technology capabilities accrued through R&D efforts that are specially tailored for environmental matters lead to the introduction of both product and process EI. These findings unravel the presence of a trade-off when firms are making decisions to commit to clean, instead of polluting technologies. Polluting technologies tend to be in the expected continuum of the existing manufacturing and R&D paths of established firms. Early adoption and existing investments in polluting technologies can easily lead to technological lock-ins unless conscious efforts are made in order to divert firm's activities towards cleaner alternatives. Unruh (2002) argues that the majority of established firms find it hard to introduce innovations with environmental benefits because these often challenge their existing position in the market. It may indeed be naive to expect generic R&D efforts to generate enough positive side effects that can tackle the environmental problems facing the world. Like many studies in the field, Carillo-Hermosilla (2006) points that a paradigm shift towards greener alternatives is unlikely to happen within the existing ways of doing business and would require explicit techno-environmental policies where … *"the policy-maker adopts the role of a guide for the market, highlighting and creating incentives for the socially desirable technology option until [...] cumulative endogenous phenomena come into play (economies of scale and learning)"* (p.718). Also, from a more theoretical perspective, we would like to highlight the necessity for broader and distant search perspectives (March, 1991) in firms' technological routines in order to succeed in environmental innovations.

Thirdly, our results confirm prior literature (Dangelico and Vocalelli, 2017; Dangelico et al, 2017; Ko and Liu, 2016) in showing that environmental market search capabilities are important for the introduction of product EI whilst having no significant influence on process EI. Product EIs are in close proximity to the customer bases of firms and have an immediate impact on the image of the company while process EI are less visible to the customers. Therefore, it is not surprising that the positive impact of environmental market search capabilities is mostly on product EI.

The study has a number of limitations that should be addressed in future research. Firstly, the most important one is the lack of a longitudinal dataset to guide our explorations in the field of capabilities. Even though the questions are structured to reflect a lag by asking firms for EI undertaken in the last years, this offers limited historical coverage. As capabilities change over time in response to environmental demands, a longitudinal dataset would offer additional insights over cross-sectional data. Secondly, although we control for regulation and demand, these drivers of eco-innovation are highly complex factors that differ across countries. Thus, applying this analysis in different national context would be the focus of future research. Finally, the coverage of the sample in this study is limited to manufacturing firms. Future studies should consider service sector firms given the recent growth of environmental service firms.

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TABLES & FIGURES

Figure 1. Sustainability-oriented capabilities for Eco-innovation: Conceptual Framework

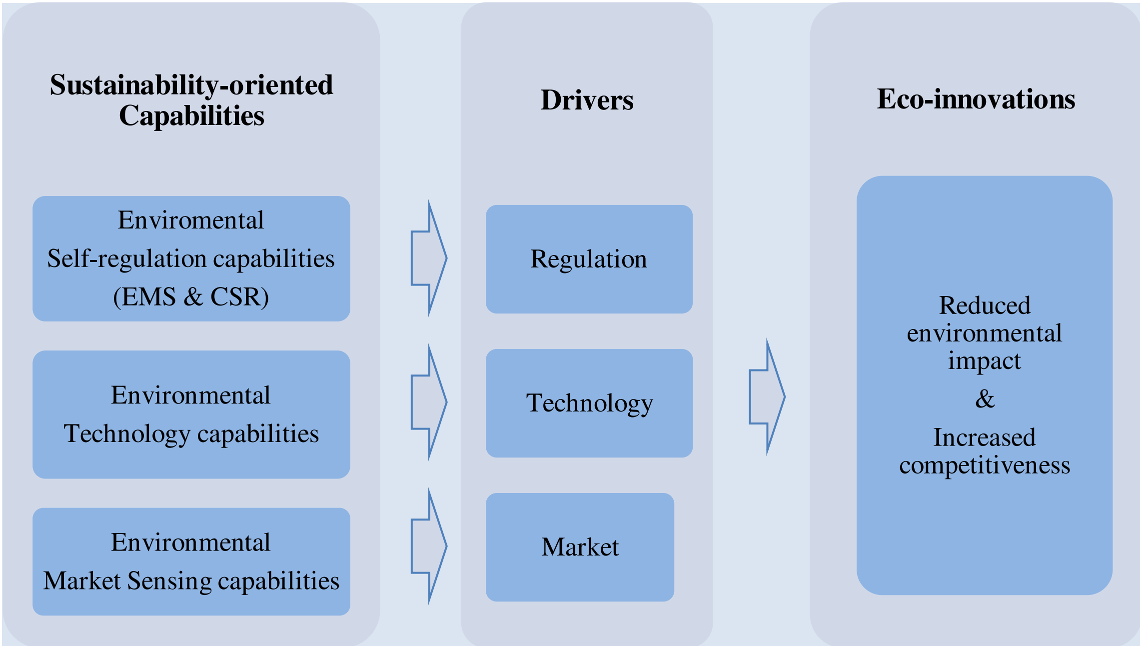

Table 1. Eco-innovation (Dependent variables)

Variables	Definition/measurement	Variable name	Obs	Mean	Std. Dev.	Min	Max
Product Eco-innovation	During the last three years, did your enterprise introduce new or improved products or services that are more environmentally friendly than those already on the market? (YES=1, NO=0).	Product EI	160	0.431	0.497	0	1
Process Eco-innovation	During the last three years, did your enterprise introduce new or improved manufacturing or production processes, delivery, transport, or distribution systems with environmental benefits? (YES=1, NO=0).	Process EI	164	0.445	0.499	0	1

Table 2. Sustainability-oriented capabilities (Independent variables)

Variables	Definition/measurement	Obs	Mean	Std. Dev.	Min	Max
	Environmental Self-regulation Capabilities					
Exec_EMS	Have you had to appoint an environmental officer at the executive level in order to implement the EMS? (YES=1, NO=0).	157	0.394	0.49	0	1
Admin_EMS	Have you had to appoint an environmental officer at the administrative level in order to implement the EMS? (YES=1, NO=0).	157	0.656	0.476	0	1
EMS	Have you implemented an Environmental Management System (EMS)? (YES=1, NO=0).	167	0.814	0.39	0	1
Exper_EMS	Number of years after adoption of EMS	119	7	4	1	32
CSR	Please rate the importance of CSR policies for your company (Not relevant/Low=0, Medium/High=1). (YES=1, NO=0).	161	0.83	0.375	0	1
	Environmental Technology Capabilities					
R&D	Does your facility have a budget for Research and Development? (YES=1, NO=0).	159	0.472	0.501	0	1
EcoR&D	Does your facility have a budget for Research and Development specifically related to Environmental matters? (YES=1, NO=0).	155	0.168	0.375	0	1
	Environmental Market Sensing Capabilities					
Market search	During the last three years, did your enterprise conduct market research for introducing new or significantly improved environmentally friendly products (goods or services) or processes? (YES=1, NO=0).	163	0.313	0.465	0	1

Table 3. Control variables

Variables	Definition/measurement	Obs	Mean	Std. Dev	Min	Max
Regulation	Please rate the importance of regulations for the environmental activities of your firm (Not relevant/Low=0, Medium/High=1).	143	0.867	0.341	0	1
Materials	Please rate the importance of reducing materials use for the environmental activities of your firm (Not relevant/Low=0, Medium/High=1).	156	0.404	0.492	0	1
Train	During the last three years, did your enterprise conduct training for introducing new or significantly improved environmentally friendly products (goods or services) or processes? (YES=1, NO=0).	163	0.607	0.49	0	1
Demand	Please rate the importance of demand for the environmental activities of your firm (Not relevant/Low=0, Medium/High=1).	160	0.638	0.482	0	1
Train	During the last three years, did your enterprise conduct training for introducing new or significantly improved environmentally friendly products (goods or services) or processes? (YES=1, NO=0).	163	0.607	0.49	0	1
International	Please rate the importance of international markets for the environmental activities of your firm (Not relevant/Low=0, Medium/High=1).	156	0.352	0.479	0	1
Size	Number of Employees.	169	2,640	11,948	8	101,000
log(Size)	log(Number of Employees).	169	5.284	1.801	2.08	11.52
Growth	Has your company increased its sales during the years 2007 to 2009? (YES=1, NO=0).	158	0.247	0.433	0	1

Table 4: Probit regression results – marginal effects

	Product EI Model 1	Product EI Model 2	Process EI Model 3	Process EI Model 4
	ENVIRONMENTAL SELF-REGULATION CAPABILITIES			
Exec_EMS	0.414	1.288**	0.49	1.106**
	(0.325)	(0.54)	(0.382)	(0.507)
Admin_EMS	-0.763**	-0.811*	-0.394	-0.397
	(0.353)	(0.484)	(0.376)	(0.551)
Exper_EMS		0.115*		0.115
		(2.51)		(1.92)
CSR	0.236	1.676*	0.139	-0.019
	(0.514)	(0.921)	(0.454)	(0.622)
	ENVIRONMENTAL TECHNOLOGY CAPABILITIES			
R&D	0.131	-0.425	-0.021	0.282
	(0.302)	(0.477)	(0.351)	(0.446)
ECOR&D	0.781*	1.654**	1.345**	1.368*
	(0.402)	(0.71)	(0.681)	(0.83)
	ENVIRONMENTAL MARKET SENSING CAPABILITIES			
Market Search	0.915***	1.829***	-0.224	0.154
	(0.327)	(0.571)	(0.367)	(0.516)
	CONTROL VARIABLES			
Regulation	-0.055	-0.689	0.412	1.092
	(0.496)	(0.869)	(0.468)	(0.714)
Materials	0.276	0.217	1.392***	1.363**
	(0.321)	(0.453)	(0.489)	(0.627)
Train	0.475	0.213	-0.163	-0.564
	(0.31)	(0.463)	(0.361)	(0.472)
Demand	0.945***	2.016***	-0.494	0.028
	(0.341)	(0.606)	(0.389)	(0.52)
International	0.317	-0.446	-0.455	-0.413
	(0.335)	(0.499)	(0.418)	(0.494)
log(Size)	0.077	0.044	0.241*	0.211
	(0.082)	(0.135)	(0.125)	(0.176)
Growth	0.395	-0.373	0.228	-0.542
	(0.376)	(0.577)	(0.487)	(0.661)
Medium Pollution	-0.592*	-1.186**	0.588	0.286
	(0.316)	(0.517)	(0.359)	(0.45)
High Pollution	-0.507	0.486	0.361	
	(0.743)	(1.343)	(0.839)	
Constant	-1.832***	-3.450***	-0.872	-2.111*
	-0.664	-1.253	-0.721	-1.187
Chi2	57.019***	69.463***	26.634***	24.808***
Observations	119	93	122	90

* p<0.10, ** p<0.05,*** p<0.010
Robust standard errors reported in brackets

Appendix A. Non-response analysis (independent group t-tests)

Variable	Respondent	n	Mean	t	d.f.	Significance (two-sided)
SIZE	0 (no)	1449	2027	-0.7322	1616	0.464
	1 (yes)	169	2640			
SALES	0 (no)	1447	61584	-1.722	1614	0.085
	1 (yes)	169	1504728			