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Innovation Strategy and Firm Competitiveness: A Framework to Support the Holistic Integration of Eco-Innovation[1]

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ABSTRACT

Although a plethora of authors have investigated the association between eco-innovation activities and firm competitiveness, the results of these studies remain inconsistent. However, very few papers take a systemic perspective. Hence, we examine the interactions between all the components of eco-innovation strategy: holistic engagement, technological innovation focus, organisational adaptation, open innovation, peculiarities of firm size. Based on data from the 2015 Community Innovation Survey conducted in Belgium and the BELFIRST database, we apply OLS and 2SLS regression models. The findings address inconsistencies in the literature by demonstrating that the outcomes of a well-managed eco-innovation strategy are better than the sum of its components. A holistic approach of eco-innovation can strengthen the competitive position of the firm. Moreover, the systemic view and the consideration of a firm's size-related characteristics permit us to draw a theoretical framework for the holistic and competitive integration of eco-innovation. It offers significant strategic guidance for managers.

KEYWORDS: Eco-innovation, Eco-innovation Strategy, Competitiveness, Corporate Social Responsibility, Management of Innovation

JEL CODES: O32, O36, Q550

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Economic growth and the improvement of living standards have traditionally been driven by innovation. Schumpeter (1942), the pioneer of work on innovation, called it “creative destruction”. However, the author certainly did not expect that, over time, the word “destruction” would acquire a completely different meaning. Indeed, technological innovation has contributed to destroying climate equilibriums, threatening the prosperity of life on Earth. Paradoxically, in the academic field, a large number of studies show that sustainable development embodies the notion of innovation (Robert *et al.*, 2014). Can innovation help to mitigate the crisis it has caused? This question gave rise to eco-innovation (EI), *i.e.* ecological innovation, which has gained in importance due to its potential to transform the economy.

EI describes those innovations that contribute to sustainable development by, *a minima*, designing ecological improvements in comparison to the whole lifecycle of relevant alternatives (Xavier *et al.*, 2017). Both technological innovations, on products or processes, and organisational innovations are concerned by EI (*e.g.* Bitencourt *et al.*, 2020; Klewitz, Hansen, 2014; Keshminder, Chandran, 2017). Researchers have examined EI from a variety of angles, such as those related to government policy (*e.g.* Porter, Van der Linde, 1995; Soltmann *et al.*, 2015), stakeholders (*e.g.* Acebo *et al.*, 2021; Munodawafa, Johl, 2019), or organisational strategies (*e.g.* Aragón-Correa *et al.*, 2008; Tamayo-Orbegozo *et al.*, 2017). This study examines EI from the organisational strategic perspective.

EI strategy is the decision-making carried out by a firm in the scope of ecological benefits to react to the changing reality (Liao, Tsai, 2018). Although EI is observed at the micro level, it is a broader process than eco-design, influencing higher spheres in the organisation and leading to more radical changes (Xavier *et al.*, 2017). The essence of EI strategy is focused on a synergy that generates superior performance (Hart, 1995; Liao, Tsai, 2018), accordingly, the question of the effect on competitiveness has arisen. Competitiveness is closely related to the value offered by the firm; it represents the ability of a company to sustainably fulfil its dual objective of meeting customer needs while making a profit (Chikán, 2008). In the discipline of strategic management, competitive advantage is necessarily the result of an innovation process (Atamer *et al.*, 2005). According to Zheng and Iatridis (2022), most companies will not embrace EI unless they think that through their implementation they can achieve returns on their economic performance.

From a strategic perspective, five variables intervene in the relations between EI and firm competitiveness. First, the literature (Andries, Stephan, 2019; Ghisetti, Rennings, 2014; Reyes-Santiago *et al.*, 2019) has discussed the way in which the EI strategy is approached, whether it is proactive and holistic or reactive and constrained. Second, scholars (Aragón-Correa *et al.*, 2008; Brasil *et al.*, 2016; Cai, Li, 2018; Cheng *et al.*, 2014; Hizarci-Payne *et al.*, 2021; Tang *et al.*, 2018; Wijethilake *et al.*, 2018; Zheng, Iatridis, 2022) have examined the effect of organisational innovations introduced to support technological EI. Third, several authors (Bitencourt *et al.*, 2020; Brasil *et al.*, 2016; Cai, Li, 2018; Cheng *et al.*, 2014; Doran, Ryan, 2014, 2016; Driessen *et al.*, 2013; Ghisetti, Rennings, 2014; Hizarci-Payne *et al.*, 2021; Huang, Li, 2018; Tang *et al.*, 2018; Zheng, Iatridis, 2022) have studied the interplay between the forms of technological EI and competitiveness. Fourth, the literature (Doran, Ryan, 2014, 2016; Huang, Li, 2018; Valdez-Juárez, Castillo-Vergara, 2020) has looked at the role that open innovation plays in the economic outcome of EI. Finally, some works (Andries, Stephan, 2019; Aragón-Correa *et al.*, 2008; Madaleno *et al.*, 2020; Przychodzen, Przychodzen, 2015; Valdez-Juárez, Castillo-Vergara, 2020; Zheng, Iatridis, 2022) show that the peculiarities of firm size affect the competitiveness of an EI strategy.

The relations between the preceding five strategic components and competitiveness have mainly been explored in isolation: the effect of one component on competitiveness. Studies have shown that EI has the potential to bring economic benefits. Porter's hypothesis (Porter, Van der Linde, 1995) about the win-win potential of EI has been verified in different research (Munodawafa, Johl, 2019). Nevertheless, the positive outcomes do not occur systematically and the literature is inconclusive on the reasons why (Cai, Li, 2018; Hizarci-Payne *et al.*, 2021; Reyes-Santiago *et al.*, 2019; Tang *et al.*, 2018; Zheng, Iatridis, 2022). Consequently, in their systematic review, Zheng and Iatridis (2022) argue that practitioners and policy makers are perplexed and need further guidance. Thus, there is a need to extend the literature by characterising cases where Porter's hypothesis holds. Our contribution will be framed in this respect by studying "how" and "for whom" EI supports competitiveness.

Accordingly, Cheng *et al.* (2014) raise the necessity of a holistic analysis of the eco-innovation programme. The authors have demonstrated, through their framework, how process EI, product EI, and organisational EI can interact effectively to foster performance. In the same vein, Brasil *et al.* (2016) emphasised the need for a holistic analysis between the organisational and technological spheres of EI. Therefore, in their systematic review, Hazarika and Zhang (2019) underline the fact that the literature has, interestingly, evolved from understanding EI as an instrumental entity to a social entity, and theoretical analysis has also shifted from a rigid neoclassical cost-benefit analysis to an evolutionary approach. The holistic analysis of EI strategy is rooted in the resource-based view of the firm (RBV) and evolutionary theory.

The theories conceptualise EI as a process by which the organisation cultivates and uses different resources for its sustainability (Aragón-Correa *et al.*, 2008; Díaz-García *et al.*, 2015). The resources of a company incorporate not only its assets, but also its information, knowledge, and processes (Munodawafa, Johl, 2019). Out of these emerge internal capabilities which, in turn, guide strategic choices and provide the basis for positional competitive advantage (Barney, 1991). As EI affects all the firm's levels, it is necessary to study EI in a holistic and path-dependent approach (Brasil *et al.*, 2016; Castiglione *et al.*, 2021; Cheng *et al.*, 2014; OECD, 2009; Pham *et al.*, 2019; Xavier *et al.*, 2020) in order to support firms in their sustainable development. However, to our knowledge, no author has extended this holistic analysis to the five components of EI strategy, previously identified. This will be the main objective of our research. We aim to develop a framework for the competitive integration of EI, based on a holistic analysis of the following variables: holistic engagement, organisational adaptation, technological innovation focus, open innovation, and peculiarities of firm size.

We use data from the European Community Innovation Survey (CIS) conducted in Belgium in 2015 to investigate how technological and non-technological EI practices directly and indirectly influence the firm's competitiveness. Overall, our study makes several contributions. While the general trend in previous studies is to consider EI as monolithic (Chen, 2022), this manuscript illustrates its importance and the way to have a broader perspective of EI strategy. The integration of EI is a complex system, presenting interactions that need to be studied. Besides, our results contribute to the literature by providing explanations for the negative effects of certain forms of EI and cooperation on firm competitiveness, as well as illustrating the peculiarities of smaller firms regarding EI. Subsequently, we propose a size-based framework for the holistic and competitive integration of EI. These findings have significant implications for managers who want to improve their sustainability performance.

The remainder of this paper is laid out as follows. Section 2 formulates the theoretical hypotheses concerning the effects of EI strategic variables on firm competitiveness. Section 3 describes the data and the specifications of the models. Section 4 presents the empirical results. Section 5 and 6 discuss the main findings and their implications as well as the limitations and avenues for further research arising from this paper.

Theoretical Framework and Research Hypotheses

Undertaking the EI exercise is not simple. EI cannot be an emergent strategy resulting from improvisation or speculative behaviour (*e.g.* Ceptureanu *et al.*, 2020; Pham *et al.*, 2019; Xavier *et al.*, 2020). Changing the firm's trajectory can be costly and risky (Laperche, Lefebvre, 2012). In particular, firms are not traditionally formatted to integrate environmental aspects in their internal domains, thus facing the "liability of newness" (Tamayo-Orbegozo *et al.*, 2017). Therefore, to assume an EI strategy, firms must accumulate knowledge and know-how and develop dynamic capabilities (Salim *et al.*, 2019). The resource-based view (Hart, 1995) emphasises that by realigning their resources towards the achievement of EI, an organisation will build 'environmental capabilities' (Albertini, 2019). Evolutionary theory states that these capabilities lay the foundation for a proactive environmental strategy and the achievement of competitive advantage (Downs, Velamuri, 2018). In this sense, *holistic engagement* is key for EI strategy, it corresponds to a proactive engagement to integrate EI at the core of overall business activities in order to create synergies. Indeed, recent literature underpins the fact that eco-innovative behaviour could only be stimulated by a comprehensive and integrated corporate philosophy (Castiglione *et al.*, 2021; Madaleno *et al.*, 2020; Pham *et al.*, 2019; Reyes-Santiago *et al.*, 2019; Tamayo-Orbegozo *et al.*, 2017; Xavier *et al.*, 2020). The knowledge and skills needed for the development of the different forms of EI are complementary (Brasil *et al.*, 2016), forming a synergistic mechanism for the integration of EI (Cheng *et al.*, 2014). According to Ghisetti and Rennings (2014), a green innovation threshold seems to be at stake and this discriminates between profitable and non-profitable innovations. These elements lead us to believe that the more the company integrates different forms of EI in its activities, the more it will benefit from synergistic effects and develop its competitive advantage. We formulate the following hypothesis:

> *H1:* The more advanced the holistic engagement in EI, the greater the competitive advantage the firm obtains.

Several authors (*e.g.* Huang, Li, 2018; Tamayo-Orbegozo *et al.*, 2017; Wijethilake *et al.*, 2018) support the idea that the competitive position can only be sustainably improved if there is an alignment between the EI strategy and the internal and external contextual factors. According to Wijethilake *et al.* (2018), technological EI need organisational innovations to influence firm competitiveness. Indeed, organisational EI can be interpreted as a means of facilitating and coordinating technical knowledge in order to eco-innovate (Keshminder, Chandran, 2017). This refers to changes in organisational structure and infrastructure coordination that enable process and product EI (Castiglione *et al.*, 2021). For Hizarci-Payne *et al.* (2021), organisational adaptation is the main driver of competitive EI. In their systemic review, Munodawafa and Johl (2019) find that human, structural, and relational resources play a pivotal role in an organisation's eco-innovative capabilities. Therefore, EI strategy depends on *organisational adaptation*, referring to the organisational changes needed for the holistic integration of EI: in the organisation of the different tasks, in the company's relations with the different stakeholders, and in the very definition of products/services (Carrillo *et al.*, 2011). This description leads us to formulate the following hypothesis:

> *H2:* Organisational innovation accentuates the relation between holistic engagement in EI and firm competitiveness.

The *technological innovation focus* is the component of the EI strategy that has been studied the most. It refers to the forms of innovations in which the firm invests. Technological EI is usually divided into product and process EI. Product EI is the development of a new product or the improvement of the characteristics of an existing product, with the aim of reducing damage to the natural environment throughout the product lifecycle (Keshminder, Chandran, 2017). Process EI consists of new production methods (for both goods and services), such as Energy and Resources Efficiency Innovations (EREI), end-of-pipe technologies, or Externally Reducing innovations (ER) (Ghisetti, Rennings, 2014), or others forms of innovations that reduce the emission of pollutants and comply with regulations (Brasil *et al.*, 2016). Some research (Brasil *et al.*, 2016; Cheng *et al.*, 2014; OECD, 2009) has shown that there are significant relations between different forms of EI. Nevertheless, as stated by previous authors, each form of EI has its own attributes, determinants, and relations with firm competitiveness. It is essential that managers are aware of this in order to implement an EI strategy with an appropriate pathway. A plethora of authors have studied the association between forms of EI and competitiveness but, as stated by Tang *et al.* (2018) or Zheng and Iatridis (2022), the results of these studies remain inconsistent. In this context, some authors have tried to clarify the right path to follow. The findings of Cheng *et al.* (2014) and Brasil *et al.* (2016) imply that companies must first engage in organisational innovation, develop the necessary infrastructure, and acquire ecological knowledge in order to be ready to improve their manufacturing processes and ultimately draft more responsible products. Specifically, process EI is often seen as less costly and less risky, and therefore the most suitable environmental solution for short-term performance development (Doran, Ryan, 2016; Tang *et al.*, 2018). However, a distinction must be made between the effect of two forms of process EI. Ghisetti and Rennings (2014) state that innovations leading to a reduction in resource or energy use (EREI) allow for a direct improvement of competitiveness. Conversely, innovations aimed solely at reducing end-of-pipe externalities such as noise, hazardous materials, or pollution in the air, water, and soil (ER) should result in a reduction in competitiveness. Even if the latter innovations benefit the environment through the externalities they reduce, they are on the margins of proactive strategies enhancing the sustainability and competitiveness of firms (Pan *et al.*, 2021). Regarding product EI, studies show that they induce positive (Zheng, Iatridis, 2022), neutral (Bitencourt *et al.*, 2020), or negative (Driessen *et al.*, 2013; Doran, Ryan, 2016) effects on competitiveness. We believe that this inconsistency can be explained by the need of synergy for eco-product innovations. This description leads us to formulate the following hypotheses:

> *H3a:* Process EI, except for ER, positively and directly influences the competitiveness of firms.
> *H3b:* Product EI has no direct influence on the competitiveness of firms; it needs to be included in a synergistic program of EI in order to have a positive influence.

Complementarity effects therefore allow certain forms of EI to positively affect firm competitiveness. Complementarity appears when firms which undertake two forms of innovation simultaneously benefit more than firms undertaking these forms of innovation separately (Schmiedeberg, 2008). The interdependence and coordination of resources, such as knowledge, skills, technical needs, or even public incentives can explain this phenomenon (Cainelli *et al.*, 2011). In contrast, substitution appears when firms which undertake two forms of innovation separately benefit more than firms undertaking these forms of innovation simultaneously (Doran, Ryan, 2014). Since there are differences in terms of resources needed, losses of productivity appear. Doran and Ryan (2014) state that only a small subset of EI activities has complementarity/substitution characteristics. In view of the conclusions of Ghisetti and Rennings (2014) and Pan *et al.* (2021), we believe that ER have little or no involvement in the creation of synergies and are concerned with substitution effects. Subsequently, since the literature suggests that the positive effect of product EI and ER is not systematic, we believe that they need complementarity effects to positively influence competitiveness. We formulate the following hypotheses:

> *H3c:* Product EI as well as ER need complementarity effects in order to positively influence firm competitiveness.

H3d: Substitution effects are mostly concerned by ER.

In view of resource dependency theory, knowledge is often considered as the most valuable resource of a company (Cabrita *et al.*, 2014; Laperche, Lefebvre, 2012). Therefore, organisational learning capacity is identified as a key factor in the success of greening the firm (Aragón-Correa *et al.*, 2008; Cabrita *et al.*, 2014; Laperche, Lefebvre, 2012; Pham *et al.*, 2019). However, the knowledge needed for EI is difficult to access internally. Firms need to expand their knowledge sources in order to identify development opportunities in line with market demand (Liao, Tsai, 2018). When the knowledge boundaries between the firm and the external environment become permeable, the firm finds itself in a so-called "open EI" mode (Ghisetti *et al.*, 2015) in which different partners can be involved: customers, suppliers, competitors, universities, research institutes, consultants, or other firms (Acebo *et al.*, 2021; Liao, Tsai, 2018). Thereby, *open innovation* is a component of the EI strategy that supports the development of EI through the integration of other actors' competence and resources in the innovation process. Ayerbe *et al.* (2020) report that the open innovation paradigm could be relevant to explain or foster the emergence and adoption of managerial innovations. Accordingly, different authors suggest that external collaboration promotes all types of EI (*e.g.* De Marchi, 2012; Triguero *et al.*, 2013) and enhances competitiveness (Valdez-Juárez, Castillo-Vergara, 2020). However, others have presented more nuanced results (*e.g.* Doran, Ryan, 2016; Fernández-Olmos, Ramírez-Alesón, 2017), which leads us to believe that the direct effect of open EI on competitiveness varies according to the type of partner. We formulate the following hypotheses:

H4a: The greater the extent of the strategy of openness for innovation activities, the greater the competitive advantage the firm obtains.
H4b: Open innovation has a direct effect on competitiveness which varies depending upon the partner (customer, supplier, scientist, group and/or other companies).

Finally, the size of the firm influences the EI process (Bos-Brouwers, 2010). As a result, small and large firms have different EI potentials (Breard, Llorente-González, 2022; Caravella, Crespi, 2022; Triguero *et al.*, 2013). The literature suggests a series of distinctive characteristics that can influence the integration and competitiveness of EI. The *peculiarities of firm size*, underlining the attributes on which managers will build, are key when it comes to introducing an EI strategy. Larger firms enjoy more financial and human resources and are therefore, in line with RBV, advantaged in developing competitive EI (Cuerva *et al.*, 2014; De Marchi, 2012). Furthermore, smaller organisations may suffer from a lack of resources related to knowledge, technology, and skilled personnel (De Jesus Pacheco *et al.*, 2017). Hörisch *et al.* (2015) have shown that company size is crucial for acquiring knowledge; given the human and financial resources available, large companies can more easily acquire information and develop expertise in sustainability management tools. Finally, for smaller firms, the lack of visibility can create an additional cost (Madaleno *et al.*, 2020).

Nevertheless, smaller firms have shown abilities to compensate for the lack of resources with a high level of flexibility (Pierre, Fernandez, 2018; Qian, Li, 2003). Their simple structure is better suited to respond quickly to environmental changes compared to the complex structures of large companies, for which organisational and strategic changes are time-consuming and costly (Qian, Li, 2003). In order to implement competitive EI strategies, small firms rely on certain organisational capabilities, in particular their ability to acquire knowledge sources, *i.e.* their absorptive capacity (Klewitz, Hansen, 2014). In this respect, Valdez-Juárez and Castillo-Vergara (2020) have shown that the innovation activities of small entities are more profitable when they are part of collaborative networks. However, these collaborative activities are also a source of transaction costs (Becker, Dietz, 2004). These risks include: loss of intellectual property, dependence on partners, opportunistic behaviour, difficulties in coordinating, managing, and controlling collaborative activities, etc. This description leads us to formulate the following hypotheses:

> *H5a:* Given their distinctive characteristics, larger enterprises are more prone to benefit directly from their EI activities compared to smaller enterprises.
> *H5b:* Given their distinctive characteristics, smaller enterprises are more prone to benefit from their network of co-operators in their EI strategy compared to larger enterprises.
> *H5c:* Given their distinctive characteristics, smaller enterprises are more prone to benefit from complementarity effects in their EI activities compared to larger enterprises.

Data and Methodology

The present paper proposes to verify the research hypotheses through six regression models relating the firm's EI strategy to firm competitiveness. In order to implement those analyses, we benefited from the Belgian Community Innovation Survey (CIS) and from the BELFIRST database.

The CIS is conducted every three years and its main objective is to measure the efficiency of the innovation systems, as well as to provide insights into certain aspects of the innovation process (*e.g.* R&D, material or knowledge acquisition). In 2015, 4,236 firms, headquartered in the Wallonia-Brussels Federation, were asked to participate in the CIS in which an additional module focusing on innovations with environmental benefits was added. At the time of writing, this is the last available data on EI in Belgium. It should be noted, however, that this is an optional module and, taking into account non-responses or incomplete answers, the sample was reduced to 1,443 firms (452 small-, 883 medium-sized firms and 108 large firms). Of the 1,443 firms in the full sample, 453 firms are engaged in EI activities. The target population is enterprises with 10 or more employees from most economic sectors[2] and the sample is stratified by sector (52 sectors at the 2-digit level of NACE rev. 2. grouped in 10 agglomerated sectors[3]), size class (four classes according to the number of employees), and region (Wallonia Region and Brussels-Capital Region). To our knowledge, no such study has used this survey; the most recent work about EI in Belgium is that by Andries and Stephan (2019) using the CIS 2009 data. These data on innovation activities (2012-2014) were complemented by information on the competitiveness of firms, obtained from BELFIRST, a database containing financial information on Belgian companies.

In light of the work of Ghisetti and Rennings (2014) and Rezende *et al.* (2019), it is appropriate to expect that the adoption of EI in 2012-2014 would take some time to have an impact. The dependent variable in our models, representing the competitiveness of firms, is the neperian log of value added (VA) in 2016 divided by the sector average VA. The VA represents the additional value that, thanks to the use of production factors, the enterprise adds to the amount of goods and services it has consumed. Compared to net profit subject to the variability of tax treatment (Vanacker *et al.*, 2011) and to turnover that does not take into account sectoral differences in goods and services consumed for production purposes (Delmar *et al.*, 2003), VA is a better indicator for measuring competitiveness. In substance, Soltmann *et al.* (2015), as well as Andries and Stephan (2019), demonstrate that VA is highly appropriate to measure the competitiveness of EI activities. Subsequently, all Belgian firms are required to report value added in BELFIRST, which allows us to consider small firms.

2. Excluding farming and forestry, hotels and restaurants, public administration, health, education, and personal and cultural services.
3. The same sectors have been used by Andries and Stephen (2019), see Appendix A.

Among the independent variables, we find mainly the different forms of EI (Table 1) and their interactions[4], organisational adaptation and collaborative activities (with customers, suppliers, scientists, other firms, or firms within the group), as well as several control variables related to financial risk, lack of resources, firm size, firm age, and sector of activity (Table 2).

Table 1. Description of EI variables

EI	Typologies		Description	Mean	Hypotheses
Environmental benefits obtained within the firm					
Process_ Material	Process EI	EREI	Lower material consumption per unit produced	0.111	H3a, H3b, H5a
Process_ Energy/CO_2		EREI	Lower material consumption or total CO_2 production	0.189	H3a, H3b, H5a
Process_ Pollution		ER	Less air, water, soil or noise pollution	0.130	H3a, H3b, H5a
Process_ Subsitutes		ER	Materials, replaced by less polluting or less dangerous substitutes	0.069	H3a, H3b, H5a
Process_ Renewables		Renewables	Fossil energy replaced by renewable energy	0.078	H3a, H3b, H5a
Process_ Recycling		Recycling*	Recycling or sale of waste, wastewater or used materials	0.160	H3a, H3b, H5a
Environmental benefits obtained during the consumption or use of a good or service by the end user					
Product_ Energy	Product EI		Lower energy consumption or CO_2 footprint	0.135	H3a, H3b, H5a
Product_ Pollution			Less air, water, soil or noise pollution	0.103	H3a, H3b, H5a
Product_ Recycling			Facilitation of product recycling after use	0.082	H3a, H3b, H5a
Product_ Lifetime			Increased product lifetime	0.076	H3a, H3b, H5a

Note: All the variables comes from the 2015 Community Innovation Survey (CIS)
* In coherence with Ghisetti and Rennings (2014). Process_recycling may either be a material-saving invention (thus EREI) or an externality-reducing innovation (ER), depending on wether it saves the usage of materials or water or, converseky, it improves the recyclability of wastes

4. Since the research hypotheses developed above, forty-five combinations of variables have been generated in order to assess the complementarity/substitution influence on the firm competitiveness. This corresponds to the variable INTER in Table 2.

The key focus of this paper is to exhibit how EI activities affect firm competitiveness. However, there is evidence of a potential for endogeneity in such regressions (Doran, Ryan, 2014; Triguero *et al.*, 2017). Indeed, this can happen when similar unobservable characteristics drive both EI activities and performance (Doran, Ryan, 2014) or when there is potential for reverse causality (Triguero *et al.*, 2017), resulting in biased estimates. To control for endogeneity, a two stage least square (2SLS) approach has been adopted. Each endogenous variable (HOL, HOL_org or HOL_nt) becomes the dependent variable in the first stage regression equation. Each is regressed on all exogenous and instrument (Ziv) variables. The predicted values from these regressions replace the original values of the endogenous variables in the second stage regression model (Flachenecker, Kornejew, 2019). In particular, the expression (1) exhibits the first stage regression.

$$X_i = \pi_0 + Z_i\pi_1 + \dots + Z_{mi}\pi_m + W_{li}\pi_{m+1} + \dots + W_{ri}\pi_m +_n + V_i \quad (1)$$

Then, according to expression (2), Y_i is regressed on the rest of the exogenous variables and the resulting fitted value of the endogenous variable $X_{i.}$

$$VA_i = \beta_0 + X_i\beta_1 + W_{1i}\beta_2 + \dots + W_{ni}\beta_{1+n} + u_i \quad (2)$$

Accordingly, six linear regression models with robust standard errors were implemented. When the modelling requires the use of the HOL variable or its combination with organisational adaptation (HOL_org), or with the extent of the network of cooperations for innovation (HOL_nt), we switch from the OLS model to the 2SLS model, which embed a relevant treatment of endogenous variable. Indeed, some variables that are known to be drivers of EI strategy engagement, such as subsidies (*e.g.* Andries, Stephan, 2019), marketing innovation (*e.g.* Hizarci-Payne *et al.*, 2021), or R&D expenditure (*e.g.* Doran, Ryan, 2016) may also affect competitiveness. The results of the endogeneity test confirm this presumption since the Durbin and Wu-Hausman tests reject the original hypothesis at the 1% significance level, thus concluding that HOL, HOL_org and HOL_nt are endogenous. The original hypothesis of "weak instrumental variables" can also be rejected since the one-stage estimated F-values are largely above 10 (Stock *et al.*, 2002). Subsequently, the robustness check (Appendix B) show clearly that there are hardly any changes regarding the value and significance of the explanatory variables if we challenge the environment of the models.

Following our hypothesis development, the sample is divided according to firm size, and the regressions will be executed in a second step. Cainelli *et al.* (2011) find considerable differences in EI activities from firms under 100 employees and firms above that figure. Considering this, analysis of variance (ANOVA) was carried out on the data, confirming that the threshold is

Table 2. Description of the othrer independant variables

Variable	Description	Source	Min	Max	Mean (Standard Deviation)	Hypotheses
HOL	The number of different forms of EI implemented	CIS	0	10	1.134 (2.148)	H1
HOL_org	HOL if the firm has undertaken organisational innovation (i.e. new principles in the organisation of procedures, new methods in the organisation of professional responsibilities and decision making, new methods in the organisation of external relations), 0 otherwise	CIS	0	10	0.747 (1.886)	H2
HOL_noorg	HOL if the firm has not undertaken any organisational innovation, 0 otherwise	CIS	0	10	0.387 (1.278)	H2
HOL_nt	HOL multiplied by the extent of the collaboration network (the number of types of partners involved in the innovation strategy), 0 if no partners	CIS	0	40	1.448 (4.786)	H4a, H5b
HOL_nont	HOL if the firm has no cooperation network, 0 if the firm has one or more partners	CIS	0	10	0.541 (1.554)	H4a, H5b
CO_cl	Cooperation with private sector client	CIS	0	1	0.101	H4b
CO_fo	Cooperation with suppliers of equipment, materials, components or software	CIS	0	1	0.191	H4b

Variable	Description	Source	Min	Max	Mean (Standard Deviation)	Hypotheses
CO_ent	Cooperation with other firms within the group, commercial consultants and laboratories, competitors and/or other companies in its sector	CIS	0	1	0.159	H4b
CO_sc	Cooperation with universities or other higher education institutions, public institutions, public or private research institutes	CIS	0	1	0.132	H4b
INTER	Forty-five interaction variables constructed by multiplying the different forms of EI two-by-two (e.g. Process_Material*Process_Energy/CO2, Process_Material*Process_Pollution, etc.)	CIS	0	1	0.059	H3c, H3d, H5c
SIZE	The size of the firm, i.e. the neperian logarithm of its total assets (k €)	BELFIRST	3.97	17.76	8.666 (1.8993)	
RISK	The total liabilities of the firm divided by the total assets	BELFIRST	0.003	21.52	0.662 (0.793)	
AGE	The number of years the firm has been in existence since its inception	BELFIRST	0	5.03	3.179 (0.722)	
RESOURCES	The firm's cash flow divided by its total assets	BELFIRST	-1.58	2.37	0.089 (0.168)	

appropriate. In this manuscript, large firms will refer to firms with more than 100 employees and small firms to the others.

Results

The estimation results for the full sample are reported in Table 3, while Table 4 and 5 consider firm size. Ignoring firm size, the first model (Table 3) shows that the VA in 2016 is positively influenced by the number of different types of EI implemented (HOL). This result being significant at 1% (p-value), H1 is therefore supported. In substance, the more global the integration of the EI is, the better the firms perform within their sector. This observation is even more true for firms that accompany their EI with organisational innovations. Indeed, in the second model, although HOL_noorg is positively related to the variable explained, HOL_org has a coefficient more than three times higher. These results being significant at 1%, H2 is confirmed.

Focusing on the incidence of each type of EI, the third model highlights significant differences. First, no type of product EI has a significant direct effect on the dependent variable. To benefit from product EI, it seems that firms must first develop the necessary resources: H3b is confirmed. For process EI, the picture is quite different. Only EREI positively and significantly ($p<0.05$) affect competitiveness, while ER aimed at reducing air, water, soil, or noise pollution are even associated with a lower performance ($p<0.1$). H3a is thus partially confirmed since, for process EI related to recycling and renewable energy, no statistically significant effect could be found. These latter EI, as well as product EI, participate in the construction of competitive advantage only when they are integrated into a comprehensive organisational approach.

As illustrated in the fourth model, the greater the extent of the network of collaborators for innovation activities is, the greater the competitive advantage the firm obtains. Compared to the variable HOL_nont ($p<0.05$), the variable HOL_nt ($p<0.01$) has a coefficient more than two times higher: H4a is confirmed. Finally, collaborations within the group and/or with commercial consultants and laboratories, competitors, or other companies in its sector ($p<0.01$), is the only form of collaborations that affects positively and directly the competitiveness of the firm. Hence, the other forms of collaborations contribute to the competitiveness of the firm as part of an interaction effect in the HOL_nt variable. The type of partner influences the direct effect of open innovation, H4b is therefore confirmed.

When considering the complementarity/substitution effects, only nine significant interactions out of a possible forty-five variables are observed. First, the results indicate that seven forms of EI display complementarity effects ($p<0.1$) influencing firm competitiveness positively:

- Product_Lifetime with Process_Pollution;
- Product_Energy with Product_Pollution;
- Process_Substitutes with Product_Energy;
- Process_Energy/CO2 with Process_Renewables.

Different elements support H3 since in the four interactions presented above, only the last one is not concerned with ER or a product EI. Adding that no direct positive effects have been found for any form of ER or product EI, it can be stated that these types of EI need complementarity effects in order to reinforce the firm competitiveness.

Regarding substitution effects, five significant interactions can be observed:

- Product_Lifetime with Process_Recycling;
- Product_Pollution with Product_Lifetime;
- Product_Energy with Process_Pollution;
- Process_Renewables with Product_Energy.
- Process_Substitutes with Product_Pollution.

Although, on the five substitution effects, no one substitution is related to EREI, only two of them are concerned with ER. These results thus offer only slight support to H3d: there is not enough evidence to state that substitution effects are mostly concerned with ER. Subsequently, all the substitution effects are constituted by at least one product EI, showing the complexity of implementing competitive eco-product strategies.

Considering firm size (Table 4 and 5), important differences are noted. First, advanced engagement in EI activities seems to be rewarded in both company sizes: HOL and HOL_org have a positive significant coefficient at 1% in the models. However, the coefficients are systematically higher for smaller companies, with similar standard deviations in corresponding models. Holistic engagement in EI activities pays off more for smaller companies, but organisational adaptation is more essential for them. Indeed, the HOL_noorg variable does not display significant results for smaller companies, while it affects competitiveness ($p<0.05$) positively for the larger ones. Regarding the direct effects of individual EI in models IIIa and IIIb, it could be seen that no forms of EI have a direct effect for smaller firms while EREI, represented by Process_Material, still has the largest positive influence ($p<0.01$)

Table 3. Full sample : regression analysis

	I (2SLS)	**II (2SLS)**	**III (2SLS)**	**IV (2SLS)**	**V (OLS)**	**VI (OLS)**
HOL	.174*** (.0.30)			.135*** (.038)	†.	†.
HOL_org		.197*** (.0.36)				
HOL_noorg		.059*** (.0.17)				
HOL_nt			.065*** (.014)			
HOL_nont			.0.27** (.012)			
CO_cl				-.013 (.093)		
CO _fo				-.099 (.069)		
CO_ent				.300*** (.075)		
CO_sc				.021 (.083)		
Process_Material					.192** (.085)	
Process_Energy/C02					.169** (.083)	
Process_Pollution					-.171* (.092)	
Process_Substitutes					.124 (.087)	
Process_Renewables					.087 (.077)	
Process_Recycling					-.028 (.069)	
Product_Energy					.055 (.089)	
Product_Pollution					.016 (.106)	
Product_Recycling					-.129 (.100)	
Product_Lifetime					.079 (.094)	
INTER						Included***
SIZE	.599*** (.120)	.596*** (.020)	.591*** (.020)	.593*** (.020)	.630***(.018)	.624***(.018)
AGE	-.040 (.038)	-.035 (.039)	-.044 (.037)	-.042 (.037)	-.054 (.0137)	-.046 (.038)

	I (2SLS)	**II (2SLS)**	**III (2SLS)**	**IV (2SLS)**	**V (OLS)**	**VI (OLS)**
RISK	-.040 (.038)	.039* (.021)	.031 (.020)	.039** (.020)	.037* (.022)	.037* (.022)
RESOURCES	.731*** (.169)	.745*** (.170)	.788 (.172)	.757*** (.168)	.782*** (.172)	.788*** (.174)
SECTORS	included***	included***	included***	included***	included***	included***
CONSTANT	-6.425*** (.181)	-6.385*** (.182)	-6.256*** (.188)	-6.346*** (.183)	-6.516*** (.177)	-6.485*** (.180)
R^2	0.695	0.696	0.716	0.716	0.733	0.739

† Variable excluded due to the presence of multiocollinearity
Note: The depend variable in all the models corresponds to firme competitiveness; standard deviations in parentheses; *p<0.1, **p<0.05, ***p<0.01
Simple: 1443 observations

on firm competitiveness for larger firms. The fossil energy replaced by renewable energy (Process_Renewables) and the decrease in energy consumption or total CO_2 production of the product (Process_Energy/CO2) both play ($p<0.05$) a positive role in the development of firm competitiveness in larger firms. The lack of resources for smaller businesses makes it difficult to enjoy any direct effects from their EI.

This is reflected in the significant and large effect of the RESOURCES control variable in model IIIb, whereas it is not significant in model IIIa. Therefore, given their distinctive characteristics, larger enterprises are more prone to benefit directly from their EI activities compared to smaller enterprises: H5a is thus supported. Nonetheless, once the launching barriers are overcome, additional engagement in the EI strategy is more beneficial in smaller companies.

Moreover, process EI related to recycling or sales of materials (Process_Recycling) negatively affects ($p<0.05$) the firm competitiveness of larger firms, as well as product EI ($p<0.1$), decreasing air, water, soil, or noise pollution (Product_Pollution). This illustrates the sensibility of EI activities even if resources are more accessible. Second, concerning the open innovation strategy, the HOL_nt variable positively affects ($p<0.01$) firm competitiveness in both the IVa and IVb models, while no statistically significant results can be found for the HOL_nont variables. No matter the size, the greater the extent of the open innovation strategy, the greater the competitive advantage obtained by the firm. More precisely, this impact on competitiveness is still greater for smaller firms; the HOL_nt variable presents a coefficient approximatively two times higher compared to the case of larger firms. Subsequently, the type of cooperator displays different results: only CO_cl has a positive coefficient ($p<0.1$) for larger firms while only CO_ent has a positive coefficient ($p<0.01$) for smaller firms. Once again, the coefficient is much higher in small firms. In view of these elements, H5b is supported. Smaller enterprises are more prone to benefit from their network of co-operators in their EI strategy.

Looking at the interaction effects, we observe much more significant variables at 10% for smaller companies. In particular, the VIa model displays seven significant complementarity effects while the VIb model displays four significant complementarities. In addition to the interactions Process_Substitutes with Product_Energy, Process_Pollution with Product_Lifetime, and Process_Energy/CO2 with Process_Renewables, present in the general model, the following complementarities exhibit significant results for smaller firms:

- Process_Recycling with Product_Energy;

- Process_Renewables with Product_Lifetime;
- Process_Substitutes with Process_Pollution;
- Process_Material with Product_Lifetime.

As in the general model, only one complementarity effect (Process_Energy/CO2, Process_Renewables) is not concerned with ER and/or product EI. More precisely, six out of the eight complementarities are concerned with an eco-product innovation, which underlines their potential for synergistic effects. In the same vein of the preceding results, only Product_Energy and Product_Lifetime, the most visible product EI, have complementary interactions with process EI.

Regarding larger firms, in addition to the significant interaction Product_Energy with Product_Pollution present in the general model, the following complementarities can be observed:

- Process_Material with Process_Substitutes;
- Process_Recycling with Product_Pollution;
- Product_Energy with Product_Lifetime.

In this model, all the complementarity effects are concerned with ER or product EI and only one interaction is not concerned by eco-product development. As fewer complementarities are observed, different forms of EI are absent from the complementarities: Process_Pollution, Product_Recycling, Process_Renewables, and Process_Energy/CO2. These results being significant at 10%, it supports H5c. Compared to larger firms, the smaller ones are more prone to benefit from complementarities in their EI activities. Nonetheless, substitution effects are also more present for smaller firms with seven significant interactions, against five for larger firms. This underlines a larger sensibility in competitive EI activities for smaller firms. In addition to the significant interactions ($p<0.1$), Process_Substitutes and Product_Lifetime with Product_Pollution, Process_Pollution and Process_Renewables with Product_Energy, and Process_Recycling with Product_Lifetime, present in the general model, smaller firms exhibit the following substitution effects:

- Product_Recycling with Process_Pollution;
- Process_Energy/CO2 with Product_Lifetime.

While, in addition to the significant interactions Process_Substitutes, Product_Energy, and Product_Lifetime with Product_Pollution, present in the general model, the following substitution effects are detected for larger firms:

- Process_Energy/CO2 with Process_Substitutes;
- Process_Recycling with Product_Lifetime;

Table 4. Small firms: regression analysis

	Ia (2SLS)	IIa (2SLS)	IIIa (2SLS)	IVa (2SLS)	Va (OLS)	VIa (OLS)
HOL	.143*** (.037)			.104*** (.040)	†.	†.
HOL_org		.160*** (.046)				
HOL_noorg		.022 (.016)				
HOL_nt			.065*** (.021)			
HOL_nont			.015 (.011)			
CO_cl				-.127 (.100)		
CO_fo				-.057 (.068)		
CO_ent				.351*** (.077)		
CO_sc				.080 (.082)		
Process_Material					.033 (.095)	
Process_Energy/C02					.037 (.093)	
Process_Pollution					-.111 (.109)	
Process_Substitutes					.144 (.106)	
Process_Renewables					.0.10 (.083)	
Process_Recycling					-.037 (.075)	
Product_Energy					.102 (.100)	
Product_Pollution					-.016 (.125)	
Product_Recycling					-.058 (.110)	
Product_Lifetime					.026 (.093)	
INTER						included***
SIZE	.480*** (.023)	.472*** (.023)	.474*** (.023)	.468*** (.022)	.493*** (.023)	.490***(.023)
AGE	-.056 (.038)	-.048 (.038)	-.059 (.037)	-.059 (.037)	-.070* (.037)	-.068*(.038)

	Ia (2SLS)	IIa (2SLS)	IIIa (2SLS)	IVa (2SLS)	Va (OLS)	VIa (OLS)
RISK	.031* (.016)	.029* (.016)	.025 (.016)	.030* (.016)	.024 (.016)	.026 (.016)
RESOURCES	.660*** (.159)	.672*** (.159)	.716*** (.164)	.686*** (.160)	.719*** (.163)	.692*** (.162)
SECTORS	included***	included***	included***	included***	included***	included***
CONSTANT	-5.464*** (.191)	-5.403*** (.190)	-5.344*** (.196)	-5.348*** (.190)	5.439***(.187)	-5.425*** (.193)
R^2	0.607	0.615	0.628	0.639	0.657	0.671

† Variable excluded due to the presence of multiocollinearity

Note: The depend variable in all the models corresponds to firme competitiveness; standard deviations in parentheses; *p<0.1, **p<0.05, ***p<0.01
Simple: 1189 observations

- Product_Pollution with Product_Recycling.

The results show that only one substitution effect is not concerned by a product EI for both sizes, confirming the intuitions from the VI model. Likewise, the division by size does not help to support H3d since interactions with ER represent a small subset of the substitution effects. The subdivision of the sample also shows that EREI can constitute substitution effects in the image of Process_Energy/CO2. Indeed, Process_Energy/CO2 interacts negatively with an increased product lifetime (Product_Lifetime) for smaller firms and with materials replaced by less polluting or less dangerous substitutes (Process_Substitutes) for larger firms. Globally, consideration of firm size allows us to detect more significant interactions as twenty different interactions are observed for both small and large companies, while only nine are observed in the VI model. When considering firm size, the part of EI having interaction characteristics is no longer a small subset (44.44%) in the sense of Doran and Ryan (2014).

Discussion and Conclusion

By broadening the holistic analysis to the five components of the EI strategy, we were able to propose a framework for the holistic and competitive integration of EI in both large firms (Figure 1) and small firms (Figure 2). As presented in both Figure 1 and Figure 2, the development of a proactive EI strategy starts with the willingness (Aragón-Correa, Rubio-López, 2007), whether free or submissive, to transform the business model. This willingness to engage in green transformation requires a progressive organisational adaptation, which is part of the social dimension (Hellström, 2007). Even if they are not as radical, the results are in line with Wijethilake *et al.* (2018)'s findings showing that EI production strategy, alone, has no impact on organisational performance. However, it is the development of EI, embedded in an organisational dynamic, that rethinks managerial practices, resources, and relations, which influences competitiveness. Furthermore, the results confirm the crucial role of external stakeholders for the EI activities. Following Liao and Tsai (2018), it appears that firms that open up their EI process by being able to absorb and transform external knowledge for innovation purposes will be better suited to benefit from their EI strategy. In particular, collaboration with commercial consultants and laboratories, competitors or other firms within or outside the group should be prioritised when building the EI strategy of smaller firms and customer collaboration should be prioritised in larger firms, as they directly reinforce the benefits of EI. Nevertheless, our results support Acebo *et al.* (2021), which show that

Table 5. Large Firms: regression analysis

	Ib (2SLS)	**IIb (2SLS)**	**IIIb (2SLS)**	**IVb (2SLS)**	**Vb (OLS)**	**VIb (OLS)**
HOL	.103*** (.036)			.091* (.054)	†.	†.
HOL_org		.119*** (.040)				
HOL_noorg		.071** (.032)				
HOL_nt			.035*** (.013)			
HOL_nont			.044 (.029)			
CO_cl				.268* (.137)		
CO_fo				-.068 (.112)		
CO_ent				.151 (.163)		
CO_sc				-.173 (.110)		
Process_Material					.441*** (.124)	
Process_Energy/ CO2					-.034 (.136)	
Process_Pollution					-.012 (.134)	
Process_ Substitutes					-.140 (.133)	
Process_ Renewables					.273** (.126)	
Process_Recycling					-.241** (.115)	
Product_Energy					.364*** (.141)	
Product_Pollution					-.250* (.133)	
Product_Recycling					-.032 (.137)	
Product_Lifetime					.044 (.197)	
INTER						included***

	Ib (2SLS)	**IIb (2SLS)**	**IIIb (2SLS)**	**IVb (2SLS)**	**Vb (OLS)**	**VIb (OLS)**
SIZE	.511*** (.045)	.511*** (.044)	.502*** (.044)	.506*** (.045)	.518*** (.047)	.498*** (.053)
AGE	-.001 (.073)	-.001 (.074)	-.004 (.071)	.010 (.070)	-.002 (.071)	.027 (.085)
RISK	.002 (.280)	-.004 (.279)	-.058 (.279)	-.001 (.277)	.043 (.304)	.037 (.033)
RESOURCES	.815 (1.123)	.844 (1.125)	.705 (1.123)	.748(1.118)	.749 (1.270)	.473 (1.541)
SECTORS	included***	included***	included***	included***	included***	included***
CONSTANT	-4.925*** (.795)	-4.903*** (.790)	-4.731*** (.796)	-4.902*** (.783)	-4.825*** (.875)	-4.683*** (1.013)
R^2	0.659	0.654	0.669	0.672	0.696	0.729

† Variable excluded due to the presence of multiocollinearity

Note: The depend variable in all the models corresponds to firme competitiveness; standard deviations in parentheses; *p<0.1, **p<0.05, ***p<0.01
Simple: 254 observations

multi-partner collaboration displays complementarity effects. Therefore, for both sizes, collaborations with suppliers, other companies, or scientific actors will certainly be necessary for the adoption or development of more sustainable solutions. Similarly, closer relationships with customers will help to comprehend their expectations and reduce the likelihood of poor design in the early stages of EI. Subsequently, firms need to be cautious when opening to knowledge sources because broadly acquired external knowledge can become difficult to manage and, after a certain point, even discourage firms from adopting an EI due to the complexity and redundancy of information inputs (Ghisetti *et al.*, 2015). This argument could explain why certain partners have not been attributed a significant positive influence in our sample.

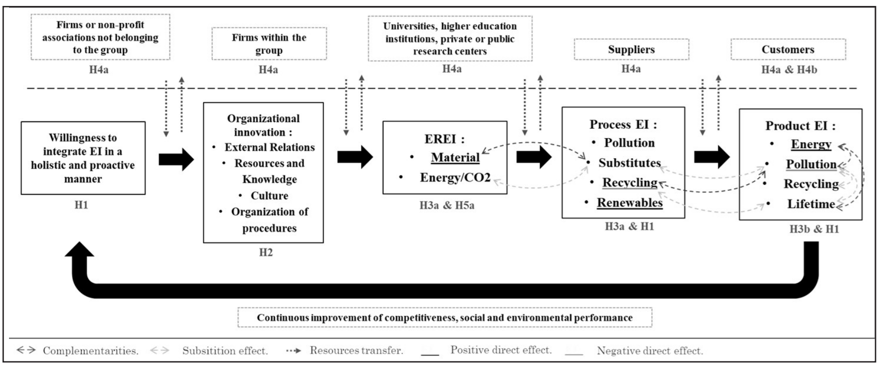
Technologically speaking, process innovation often equips existing production processes with advanced techniques which, in turn, improve the ability to add new product features to meet market needs. For effective greening, the early stages should focus on preventive solutions that make the company more efficient (EREI), not curative end-of-pipe solutions (ER). Interestingly, EREI present direct positive effects and very few negative interactions. This form of innovation seems to be a perfect candidate to initiate the technological development of an EI strategy (Figure 1 and 2).

As shown in Figure 1, other forms of eco-process innovations participate in the development of firm competitiveness. For larger firms, from the introduction of the EI strategy, investments in renewable energies have to be considered as the results show a direct influence on firm competitiveness. The same statements can be advanced for product EI, for which only EI reducing energy consumption and/or a CO_2 footprint display a direct influence on firm competitiveness. At this stage, interactions between the different forms of EI will play a significant role. It becomes crucial to know which are the complementary and the substitute forms of EI in order to transform the firm's activities efficiently and develop a competitive eco-product.

Doran and Ryan (2016), along with Driessen *et al.* (2013), stated that the firm's eco-product strategy can lead to lower competitiveness, especially if the EI strategy is not appropriate. The substitution characteristics of eco-products can be at the origin of those negative performances. Indeed, product EI appear in a vast number of substitution effects. Nevertheless, product EI also show a large potential for complementarities, underlining the role of processes, organisational structure, and resources in the competitiveness of products. This is in line with Cheng *et al.* (2014) and Brasil *et al.* (2016), who consider that firms need to be ready for eco-product development. Hence, different eco-directions could be taken for the technological development of the firm. In light of our results, some of them are more appropriate. Based on

Figure 1, we could point to various examples for an efficient development in large companies. For instance, in first steps, a firm could seek to reduce material consumption per unit produced and to develop renewable energy. These two forms of EI will permit a direct improvement in competitiveness through a reduction of costs. Then, once ready, the firm could focus on the technological development of products. Two forms of complementary EI could be targeted: development of a solution reducing energy consumption and/or the CO2 footprint, and the increased lifetime of the solution. The first one leads to a direct improvement in firm competitiveness and, with the second one, to an indirect improvement through a complementarity effect. Consumers value these two solutions since they enable a reduction in usage costs, both economic and environmental.

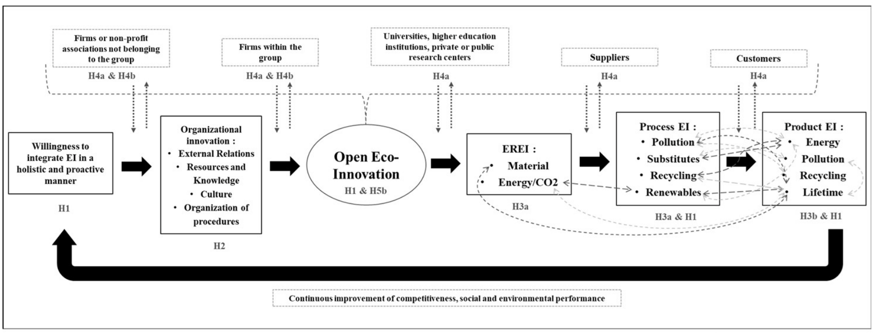
Figure 1: Framework for the holistic integration of EI in larger firms



For smaller firms, many more interactions were identified. There is a greater sensibility in the EI strategy, so opening up the strategy to relevant partners before dedicating important resources in technological development is paramount (Figure 2).

As stated by Caravella and Crespi (2022), firms that are too small are not sufficiently resource-based to deal with EI's major complexity and to extract value from these innovation channels. They present, on average, a lack of experience and capabilities that could be found in the external environment (Fernández-Olmos, Ramírez-Alesón, 2017; Valdez-Juárez, Castillo-Vergara, 2020). However, once they manage to engage in an advanced EI strategy, our results show that the reward is greater. Based on Figure 2, we can point to different examples of efficient technological development in smaller firms. For instance, a firm could first focus on reducing energy consumption and/or total CO_2 production in its process. Then, the firm could benefit from complementarity by investing in renewable energy, seeking to increase its product lifetime and reducing the material consumption per unit produced. Although smaller companies have difficulties to build competitive EI, the implementation of these four forms of EI will benefit from complementarity effects, reducing marginal complexity in order to eco-innovate. The marginal resource investments for each form of these EI is decreasing, making it easier to take advantage of each of them.

Figure 2: Framework for the holistic integration of EI in smaller firms



<-> Complementarities. <-> Subsitition effect. ···▸ Resources transfer. ___ Positive direct effect. ___ Negative direct effect.

Along the way, in a logic of continuous improvement (Xavier *et al.*, 2020), technological EI will be more radical, ranging from modification and redesign to the development of alternatives and the creation of new markets (Rashid *et al.*, 2014). By following the proposed paths, the differentiation strategy and/or the cost-leadership strategy (Díaz-García *et al.*, 2015) has more chance to be profitable economically, but also with regard to the social and environmental aspects. Indeed, from an evolutionary perspective, a change in routines (*i.e.* the regular and predictable behaviour patterns encompassing all activities within the firm) will be at stake, forming the essential EI capabilities. Given the rising price of energy and raw materials, as well as the conflictual geopolitical context in Europe, this scheme will be increasingly relevant for companies.

Theoretical Implications

Our study brings a fresh regard to the competitiveness of EI at firm level, questioning the 'how' and 'for whom' EI could be profitable.

First, whereas research on EI tends to consider EI as monolithic (Chen, 2022), this paper shows the importance of a holistic analysis of EI strategy in order to resolve inconsistencies in the literature and to guide managers towards competitive strategies. Based on our theoretical framework, we have identified, defined, and interacted five variables that comprise the EI strategy, namely: holistic engagement, organisational adaptation, technological innovation focus, open innovation, and peculiarities of firm size. This unpacking of EI strategy represents a major theoretical contribution on which future research can build.

Second, we contribute to the environmental management literature by showing that the holistic analysis of EI at the firm level is crucial. In order to develop sustainable business models, firms need to consider the three dimensions of the Triple Bottom Line (environmental, economic, and social) in a holistic relationship with the organisation. The process of integrating EI is a complex system, presenting interactions that need to be studied. Indeed, from the system point of view, the outcomes of a well-managed EI strategy are better than the sum of its components.

Finally, we observed that the way to implement a competitive EI strategy is highly dependent on firm size. In substance, smaller firms have more difficulty in dealing with EI's complexity. Nevertheless, we noticed that the smaller the size of the company, with more flexibility, more proximity between members and business units, allows for greater synergies. In this respect, we advance knowledge by showing that, when firm size is considered, a considerable number of EI present interaction effects.

Managerial Implications

The present findings contain managerial implications as a size-based framework for the holistic and competitive integration of EI have been developed.

First, based on our results, we were able to suggest some paths that are driving complementarities. In particular, seeking savings in the short-term through efficiency innovations is quite appropriate. Thus, process EI presenting positive effects on competitiveness are all related to energy savings or to savings in raw material consumption. At the same time, customers are willing to pay a sufficiently profitable premium, in the case of larger firms, for products with a longer lifetime. This seems highly relevant in view of recent events and the soaring price of energy and raw materials. It is essential to consider the interactions of these forms of innovation with the other forms in order to create positive innovation dynamics, both in the short and long term. Our theoretical framework shows complementarities with other forms of product or process EI, but also substitution effects, since the positive outcomes are not ubiquitous. In particular, product EI are mainly sensitive to interaction effects, which explains the nuanced results of previous research and indicates an important potential for synergies.

Subsequently, our results show that holistic engagement requires an organisational management system adapted to EI needs. Tools such as the Eco-Mi, proposed by Xavier *et al.* (2020), exist and can guide companies. In particular, the opening of the firm's borders, which fosters open innovation, should be a central element of the organisational management system. Developing a competitive EI strategy is not something to be done in isolation, and this is even more true for smaller firms. The synergistic effects decrease the marginal complexity to eco-innovate and increase the return on investment. Consequently, our results must motivate managers of small organisations and their partners to eco-innovate since we show that their engagement is rewarded by significant competitive advantages, even greater than for large companies.

Limitations and Future Research

Although, in this paper, we were able to discuss the results with a dynamic and size-based perspective, most studies on EI, including our own, limit the focus on innovation characteristics (*e.g.* quality, generality, radicalness and originality). In addition, sectoral differences for EI competitiveness could intervene, which is not sufficiently taken into account in our work. Hence, new quantitative as well as qualitative studies, offering more depth and specificity in the investigation, may help to complete our conceptual framework. Similarly, the managerial revolution necessary for EI would deserve to be studied more closely. More precise data are needed, and the use of qualitative analysis seems appropriate. Also, the development of supporting tools specific to the EI's management system, which take into account size differences, is an interesting research perspective.

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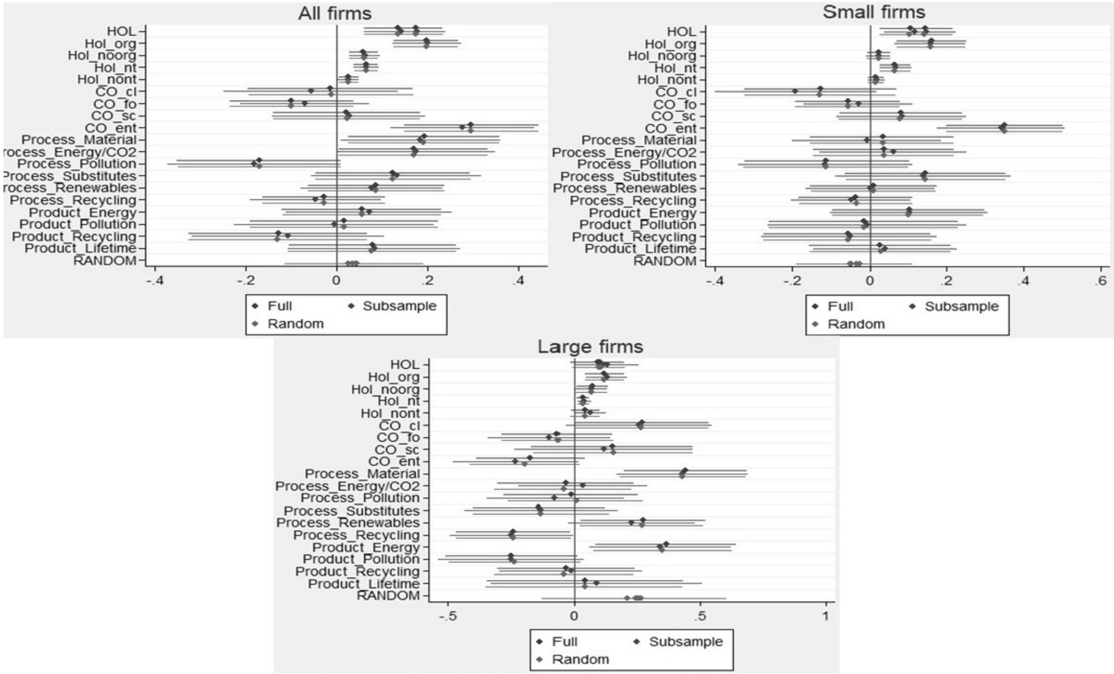
Appendices

A. Sector description

Sector	NACE Codes
Tobacco, food (Low-tech)	10-12
Wood, paper, publishing (Low-tech)	16-18
Pharmaceuticals, chemicals (High-tech)	20,21
Metal (Low-tech)	24,25
ICT, electronics, machinery, vehicles (High-tech)	26-30
Other industries (Low-tech)	5-9, 13-15, 19, 22-23, 31-39
Wholesales trade (Low-tech)	46
Transport, warehousing (Low-tech)	49-53
ICT, engineering, and R&D services (High-tech)	59-63, 71-72
Other services (Low-tech)	58,64-66,73

B. Robustness check



Description: In order to carry out robustness check, all the six regression models (see DATA AND METHODOLOGY section) have been run on random subsamples corresponding to 89.74% of the full sample (1295 firms), 89.76% of the large firms sample (228 firms) and 89.74% of the small firms sample (1067 firms). Then, we have checked if the coefficient in our regressions remain robust if we physically intervene in the specification of the model by generating a random variable (RANDOM). The graphs display the comparison of the coefficient and confidence intervals, except the CONSTANT, INTER and control variables
Note: Almost any changes have been observed regarding the insignificant properties. This is also to for the interaction variables. (INTER)