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Knowledge absorption pathways for eco-innovation: an empirical analysis of small and medium-sized enterprises in the European Union

Miyana Yoshino
University of Sussex, Brighton, UK
Benjamin Sadlek
Syracuse University, Syracuse, New York, USA
Masaru Yarime
The Hong Kong University of Science and Technology, Hong Kong, China, and
Adnan Ali
Xi'an Jiaotong University, Xi'an, China

Abstract

Purpose – This study contributes to the literature on eco-innovation (EI) and the circular economy (CE) by providing insights into the factors of external knowledge absorption that facilitate the adoption of a subset of EIss called proactive-EIs. Proactive-EIs involve collaborations among multiple stakeholders, the use of technical knowledge and a greater level of investment than other innovations. In this study, the environmental actions taken by small and medium-sized enterprises (SMEs) in resource-intensive sectors in the European Union (EU) were observed, and elements related to the national context were compared.

Design/methodology/approach – The national innovation system (NIS) perspective was adopted using a multilevel framework to assess the determinants of proactive-EIs among SMEs in the EU. The framework involves three levels: micro- (environmental awareness), meso- (external collaboration and intra-industry agglomeration) and macro- (economic complexity, trade openness and government research and development [R&D]). The survey data of 6,188 SMEs in resource-intensive sectors were analysed using a binary logistic regression.

Findings – The results showed that public awareness, economic complexity and public sector R&D positively influenced SMEs' adoption of proactive-EIs, whereas external collaboration and sectoral agglomeration negatively influenced adoption.

Originality/value – Among the existing empirical studies on EI, areas related to external knowledge-based innovations and systematic assessments of heterogeneity among EU member states remain underexplored. This study contributed to the literature by assessing the conditions surrounding external knowledge absorption. The findings contribute to the green entrepreneurship literature in the context of developed economies and offer insights for managers and policymakers seeking to promote EIs.

Keywords Circular economy, Eco-innovation, Cleaner production, Knowledge absorption, Open innovation, European SMEs, National innovation system

Paper type Research paper

1. Introduction

The use of primary materials is projected to increase almost twofold from 89 Gt in 2017 to 167 Gt in 2060 worldwide (OECD, 2019). Thus, there is a global need to shift to a circular economy (CE) and for supply chains to support the circularity of material use, including the recycling and reuse of materials (Brydges, 2021; Gaustad *et al.*, 2018; Jawahir and Bradley, 2016). The EU has been at the forefront of the transition to CE since the introduction of the CE Action Plan in 2015, which established a long-term approach to the transition. Small and medium-sized enterprises (SMEs) are especially important for this transition in the EU

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because of their environmental and economic impacts: they account for 70% of industrial pollution and 40–45% of all industrial air emission, water consumption and energy consumption levels, and they produce 50% of Europe's gross domestic product (GDP) (European Commission, 2020; Ormazabal *et al.*, 2018).

To maximize the role of SMEs during the shift to a CE, the EU has emphasized the importance of increasing businesses' capacity to adopt *eco-innovations* (EIs), which include new ideas, behaviours, products and processes that reduce environmental impacts and whose nature can be technological, organizational, social, or institutional (European Commission. Directorate General for Environment. and University of the West of England UWE. Science Communication Unit., 2020; Rennings, 2000; Sehnem *et al.*, 2022). Those EIs that require upfront investment, external collaboration and technical knowledge and are considered *proactive-EIs,* whereas others undertaken due to cost or regulatory pressures are considered *reactive-EIs* (Chen *et al.*, 2016; Darnall *et al.*, 2010; Johl and Toha, 2021). The EU has implemented several green initiatives involving SMEs, such as the Green Action Plan for SMEs in 2018 and funding from the European Regional Development Fund and Cohesion Fund supports the competitiveness of SMEs in the least developed regions. This should, in principle, facilitate a more equitable adoption of proactive-EIs across the EU. In 2021, as part of the Competitiveness of Enterprises and Small and Medium-sized Enterprises under the Single Market Programme (SMP-COSME), the Local Green Deals Blueprint was established to support cooperation and learning among stakeholders and thus promote less polluting, sustainable industrial systems and business practices (European Commission, 2021a,b). Even so, there remain significant disparities between the EI adoption rates of countries in the EU (Bassi and Dias, 2019).

Previous empirical studies have assessed the determinants that incentivize SMEs in the EU to undertake EIs (Brogi and Menichini, 2021; Horbach, 2016; Jové-Llopis and Segarra-Blasco, 2018). Among the identified determinants, the absorption of external knowledge was found to play a critical role in the adoption of proactive-EIs. However, the factors that determine the disparities between the different national contexts have not been sufficiently explored (Asimakopoulos *et al.*, 2020; Moilanen *et al.*, 2014). One approach to examining the differences between member states is to compare the national innovation system (NIS), which is a tool that describes the interplay of actors and processes that produce technological innovations and enhance competitiveness and economic growth (Acs *et al.*, 2016; Souzanchi Kashani and Roshani, 2019).The development of an NIS has been found to enhance environmental performance at the country level (Fernandes *et al.*, 2022). In addition, a strong relationship between firm performance and EIs has been found in countries with lower human development indexes and more environmental problems (Bitencourt *et al.*, 2020).

This study contributes to the literature on NIS and green innovation by highlighting the pathways within a nation that facilitate external knowledge absorption for proactive-EI adoption among EU SMEs. Against this background, a multiple-level perspective (MLP) approach was taken to address the limitations of the empirical literature, largely employing the resource-based view, and a systematic and integrative perspective was adopted to assess SME behaviours (Demirel and Danisman, 2019; He *et al.*, 2018). This paper consists of five other sections: Section 2 introduces the conceptual framework and the relevant strands of literature; Section 3 describes the six hypotheses and their bases in the literature; Section 4 presents the data and methodology of the study; Section 5 presents the results; and Section 6 concludes the paper with a discussion of the findings and the managerial and policy implications.

2. Theoretical framework

2.1 Proactive and reactive eco-innovations

SMEs in the EU adopt a variety of innovations that improve resource efficiency and promote a CE, but certain innovations require greater levels of investment and external engagement on behalf of the firms than others. EIs that promote circularity in production, require some form of external collaboration and have high upfront investment costs are categorized as *proactive-EIs* (Chen *et al.*, 2016; Darnall *et al.*, 2010; Yang *et al.*, 2018). Proactive-EIs actively alter production processes and shift the linear mode of production towards a low-carbon CE by increasing the reuse and recyclability of materials (Bassi and Dias, 2019; Garrido-Prada *et al.*, 2021) and shifting energy inputs from fossil fuels to renewable sources. Proactive-EIs share characteristics of open innovations that involve the absorption of external ideas and have been found to be essential drivers of EIs (Alawamleh *et al.*, 2018; Almeida, 2021; Pichlak and Szromek, 2021; Valdez-Juárez and Castillo-Vergara, 2021). For example, designing new products to enhance recyclability and improve reverse logistics processes may require information gathering and cooperation between a firm's supply network, partners and consumers (Ceptureanu *et al.*, 2020).

Reactive-EIs are innovations that are commonly undertaken by enterprises to lower resource and energy use and the overall cost of inputs. They may be driven by regulatory pressures to reduce waste and pollution, sometimes referred to as "end-of-pipe" actions (Frondel *et al.*, 2007; Mantovani *et al.*, 2017; Triguero *et al.*, 2013). Reactive-EIs tend to be more commonly adopted by firms than proactive-EIs are (Anon, 2018). Unlike proactive-EIs, these innovations do not radically alter the linear cycle of production. In some cases, they may increase the overall use of materials due to the Jevons effect; that is, the lowered costs of resources may cause an increase in demand (Lange *et al.*, 2021). The main distinctions considered in this study are that proactive-EIs require more coordination or interactions with external actors and fundamentally alter the linear cycle of production.

2.2 External knowledge absorption

Establishing an effective EI strategy requires a firm to embrace changes and adapt to a dynamic and complex environment. Absorptive capacity (AC), which measures a firm's ability to incorporate and apply external knowledge, plays an important role in the implementation of EIs (Aboelmaged and Hashem, 2019; Salim *et al.*, 2019). Among the resources available to firms, knowledge is commonly highlighted as essential for the success of EIs. This is because EI implementation requires a broad base of technological and nontechnological knowledge on institutional factors, the adoption of management systems, the implementation of complex regulations and the formation of sustainable supply chain networks (Triguero *et al.*, 2014).

The capabilities of SMEs to cultivate knowledge internally are limited; therefore, obtaining knowledge from external sources is vital for commercial success (Chaochotechuang *et al.*, 2020; Valdez-Juárez and Castillo-Vergara, 2021; Xiao *et al.*, 2021). SMEs in developed EU economies may be motivated to implement new technologies and adopt new business practices to signal their green investments in the marketplace (Corrocher and Solito, 2017; European Commission, 2021a, b). In contrast, SMEs in developing economies are more resource dependent and responsive to environmental pressures that cause large changes in commodity prices or material, energy and agricultural product stocks (Aboelmaged and Hashem, 2019). Therefore, AC plays a substantial role in the European SME context.

Bodas-Freitas and Corrocher (2019) assessed the role and benefits of external support in the adoption of resource-efficient practices, differentiating between direct financial support and indirect support such as external consulting. They found that, unlike financial support, indirect support could not only reduce production costs but also facilitate the adoption of process reengineering, in turn supporting the adoption of other sustainable measures. Further, Horbach (2016) reported that internal research and development (R&D) is important for reactive-EIs in the individual production processes of European firms, whereas external knowledge is important for newly developed technologies such as CO_2 for proactive-EI implementation by SMEs in the EU is also supported by the findings of Triguero *et al.* (2014)

study, which showed that knowledge-related drivers, technological capabilities, management capabilities and knowledge networks have significant impacts on the adoption of cleaner technologies. Furthermore, Triguero *et al.* (2016) found that SMEs that valued these capabilities had a high proportion (>30%) of EI investments. This has meaningful implications for the implementation of proactive-EIs, which typically require high levels of investment.

2.3 National innovation systems and the multilevel perspective

Although policy programmes have been introduced at the EU level to encourage green entrepreneurship, there are significant differences among member states about SMEs' adoption of EIs (Horbach, 2016). These differences were captured by measuring the performance of each member state's national innovation system (NIS) and describing the interactions among actors that generate technological innovations and boost competitiveness and economic growth. Building on the findings of Fernandes *et al.* (2022) study, which demonstrated that an enhanced NIS has a positive impact on a country's environmental sustainability, we investigated the national factors that facilitate the adoption of proactive-EIs among SMEs – an understudied area of research (Aboelmaged and Hashem, 2019; de Jesus and Mendonça, 2018; Kiefer *et al.*, 2021).

To develop a better understanding of an NIS that favours green entrepreneurship, a multilevel perspective (MLP) was adopted to describe long-term sociotechnical transition processes. The MLP complemented the NIS perspective, as it enabled us to focus on the importance of the interplay between three different societal layers in promoting the uptake of new technologies (Markard and Truffer, 2008). It was also used to describe the sociotechnical transition to a CE at the macro-, meso- and micro-levels (Díaz-García *et al.*, 2015). In the context of this study, the macro-level refers to national economic contexts and comparisons of different economies and their public investments in green research and development; the meso level describes the level of interactions between SMEs and other sub-governmental organizations; and the micro-level describes how local interactions and the environmental awareness of individuals in a large population affect the adoption of proactive-EIs.

The success of SMEs in implementing proactive-EIs depends on the interactions between different industry and governmental stakeholders and among consumers (Triguero *et al.*, 2022). Analysing an NIS using the MLP framework can account for multiple dimensions of the sociotechnical transition process, helping policymakers and managers identify leverage points to enhance the innovative performance and overall competitiveness of SMEs. Figure 1 describes the MLP framework of this study.

3. Knowledge absorption pathways for proactive-EIs

The MLP framework was used to observe how SMEs interact with the economy at the micro-, meso- and macro-levels. Previous empirical studies on SMEs' propensity to adopt EIs have focused on one or more of these dimensions and influenced the theoretical formation of the MLP framework and hypotheses described below.

3.1 Micro-level determinants

Micro-determinants are implementation incentives that affect individual actors on the supply and demand sides, and they determine the overall demand for EIs. The demand side encompasses customers' demand for EI products and services, whereas the supply side accounts for firms' demand for EIs (Chistov *et al.*, 2021; Ghisellini *et al.*, 2016; de Jesus *et al.*, 2016; Manniche and Testa, 2018).

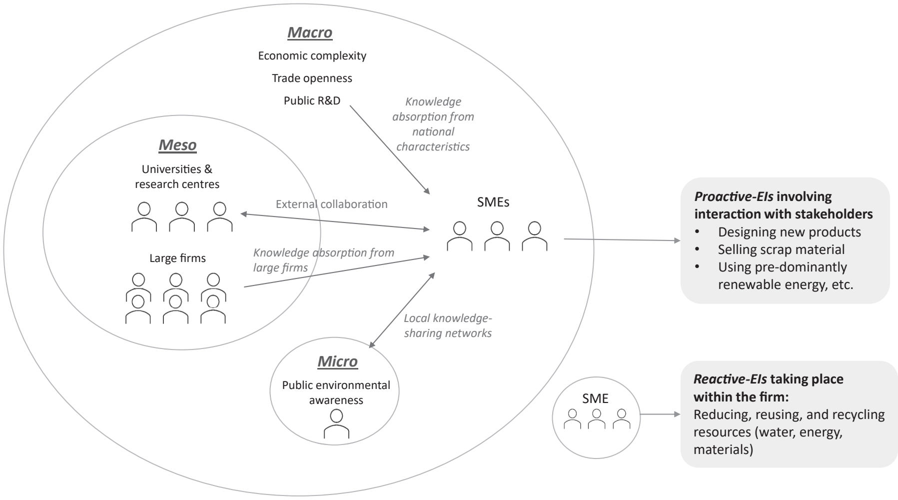


Figure 1.
Multilevel perspective on external knowledge absorption for proactive-EI

Source(s): Author's own creation/work

3.1.1 Environmental awareness of individuals. Purchasing environmental products or services typically involves paying an additional price for existing alternatives and thus requires the purchaser to be willing to pay an environmental premium (Puska, 2019). Environmental awareness has been verified to be an important contributor to EI implementation (Jun *et al.*, 2021; Melander, 2018). A high level of environmental awareness will lead to an increased demand for products and services with enhanced sustainability, putting the least sustainable firms at a competitive disadvantage (Galbreth and Ghosh, 2013). The importance of environmental awareness for encouraging EI adoption is higher for SMEs than for large firms because small firms generally don't have the resources required to expand their customer base (Raymond and St-Pierre, 2004). It has been reported that finding customers is one of the dominant concerns of European SMEs (European Central Bank, 2021). Innovation theory also supports the importance of customer demand, with demand pull and technology push as the main drivers of technological development (Török *et al.*, 2019).

Environmental awareness on the demand side induces firms on the supply side to absorb external knowledge relevant to adopting EI measures (Soetanto *et al.*, 2022). Furthermore, environmental awareness among supply-side actors creates the conditions necessary for knowledge absorption and environmental innovation, which means that more business actors will proactively seek out knowledge that encourages the adoption of practices with low environmental impacts (Lewis *et al.*, 2014; Mitchell *et al.*, 2011; Díaz-García *et al.*, 2015). SMEs tend to perceive environmental practices as additional burdens due to the costly initial process of adoption (Aristei and Gallo, 2021; Orji *et al.*, 2019). When employees have high levels of environmental awareness, SMEs are less likely to face such reluctance to initiate green measures (Thomas *et al.*, 2021).

Apart from environmental awareness on the supply and demand sides of an economy, increased awareness among a country's population will create a favourable stakeholder environment and result in external pressures that induce SMEs to adopt EIs. Large firms with high social visibility and internal resources are more likely to adopt environmental measures than SMEs. However, a data analysis of OECD countries revealed that small firms proactively adopt environmental initiatives in countries where stakeholder pressure is high

(Darnall *et al.*, 2010). When faced with external pressure for environmental consideration, small firms with limited resources are less likely to invest in initiatives in the opposite direction of the pressure, such as environmental lobbying (Bowen, 2000).

H1. European SMEs in a country with high environmental awareness are likely to adopt proactive-EIs.

3.2 Meso-level determinants

Meso determinants are factors that affect EI in the organizational context and include network-related effects such as inter-firm collaborations, public–private partnerships and supply chain networks (Chistov *et al.*, 2021; Ghisellini *et al.*, 2016; de Jesus *et al.*, 2016; Manniche and Testa, 2018).

3.2.1 External collaboration. Although it has been proven that internal R&D investment facilitates a firm's ability to adopt EIs, setting up an R&D investment scheme and increasing knowledge capacity internally is an intricate process for most firms (Horbach and Rennings, 2013). Therefore, external collaborations are important for SMEs to acquire new capabilities and knowledge (Albort-Morant *et al.*, 2018; Bitencourt *et al.*, 2020; González-Moreno *et al.*, 2019; De Marchi, 2012). Compared to other types of innovation, EIs typically involve high levels of coordination because they require consideration of the entire life cycle of a product or process (Andersen *et al.*, 2009). Empirical studies have demonstrated that green innovations benefit more from partnerships with external organizations than non-green innovations (Borghesi *et al.*, 2015; de Marchi and Grandinetti, 2013; De Marchi, 2012) and that collaboration acts as a mediator of AC (Aboelmaged and Hashem, 2019).

Supply chain networks of material suppliers, process suppliers and customers are among the most common sources of partners for firms (de Marchi and Grandinetti, 2013). Dangelico *et al.* (2013) found that collaborations with supply chain actors were effective for the adoption of green product designs among Italian firms in the textile industry. Firms can also seek partners outside organizational boundaries, such as academic institutions that provide basic research knowledge capacity. Arroyave *et al.* (2020) found that university cooperation had a significant effect on the development and breadth of EI adoption among Spanish manufacturing firms. Other entities that have been verified as effective collaboration partners are governmental bodies, industry associations, local authorities, nongovernmental organizations (NGOs) and consultancies (Burch *et al.*, 2016; Cassetta *et al.*, 2022; Dangelico *et al.*, 2013; Pathirana and Yarime, 2018).

Studies have indicated that external collaboration is effective for inducing proactive-EI. A data assessment by Triguero *et al.* (2013) showed that European SMEs that gave importance to collaborations with research institutes, agencies and universities exhibited high proactivity levels when adopting a product, process, or organizational EI. de Marchi and Grandinetti (2013) reported that a high number of collaboration partners and the importance that manufacturing firms give to external organizations increase the likelihood of EI adoption to address a broad range of environmental impacts.

H2. European SMEs in countries that have a high rate of collaboration with other firms and entities for innovative activities are likely to adopt proactive-EIs.

3.2.2 Intra-industry agglomeration. The adoption of proactive innovations is likely to be costly and resource prohibitive for SMEs (Ghenţa and Matei, 2018; Grafström and Aasma, 2021), as some innovations may require resources to modify entire market chains (Rizos *et al.*, 2016). Horbach, 2016 noted that a firm's proximity to superior knowledge infrastructure favours EI adoption and benefits local innovation systems; this could facilitate SMEs' adoption of EIs through knowledge spillovers and technology transfers. When there is an industrial agglomeration, it can promote opportunities of external knowledge transfer by employees moving between companies or the provision of external consulting. Thus, SMEs can benefit from agglomeration by adopting EIs via the transfer of knowledge and economies of scale (Pinget *et al.*, 2015). The positive effect of agglomeration on innovation adoption has been empirically proven. Pinget *et al.* (2015) conducted an analysis of French SMEs and found that being part of a cluster increased the probability of an SME adopting EIs. Daddi and Iraldo (2016) analysed the effectiveness of the EU Eco-Management and Audit Scheme (EMAS) in an industrial cluster in Italy and found that the cluster's improvements in the environmental performance indicator were greater than the European average. Arranz *et al.* (2019) measured agglomeration **as** the density of companies in a region and verified that it facilitates EI development. Knowledge spillovers from agglomeration can occur both within an industry and across industries. Several studies have provided evidence of both types of externalities and indicate that within-industry spillovers are more significant in Europe (Autant-Bernard *et al.*, 2011; Van Der Panne, 2004).

H3. European SMEs operating in countries where resource-intensive sectors have high economic shares are likely to adopt proactive-EIs.

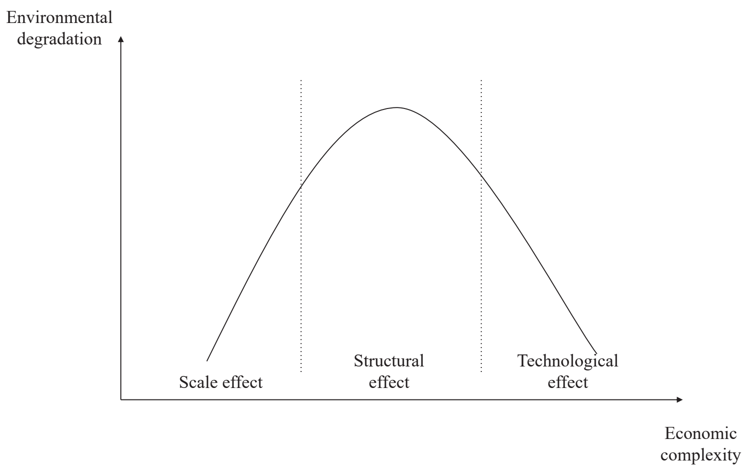
3.3 Macro-level determinants

Macro-level determinants constitute the national characteristics that affect the adoption of EIs. These are largely outside the control of an individual firm, such as the amount of research and development devoted to green R&D in the public sector (Chistov *et al.*, 2021; Ghisellini *et al.*, 2016; de Jesus *et al.*, 2016; Manniche and Testa, 2018).

3.3.1 Economic complexity index. Firms typically implement multiple EI measures due to their complementary benefits, which requires the utilization of different sets of knowledge. For example, eco-process and eco-product innovations can enhance the effects of eco-organizational innovations, leading to increased firm performance (Cainelli *et al.*, 2012; Cheng *et al.*, 2014; Moreno-Mondéjar *et al.*, 2020). The knowledge intensity required for EIs has been linked to the Economic Complexity Index (ECI), which is a measure of a country's knowledge diversity and efficient combination of knowledge (Chu and Le, 2021). Based on the rationale that the technological level and production factors of a country are reflected in its exported manufactured goods, ECI is determined by the portfolio diversity of export goods and their ubiquity – that is, the number of the countries able to produce the products (Hausmann *et al.*, 2013).

A country's stage of development and its relation to levels of environmental degradation and technological development has long been described by the Environmental Kuznets Curve (EKC) hypothesis, in which per capita income is a proxy for economic development (Niu *et al.*, 2018; Pincheira and Zuniga, 2021). However, recent EKC studies have used the ECI instead of GDP per capita. The relationship between the ECI and environmental degradation is depicted in Figure 2. In the initial period of economic development, countries experience the "scale effect": environmental degradation increases due to larger amounts of resources and activities being required to develop products with higher levels of sophistication. After countries attain increased economic complexity and diversified technical capabilities, the "technological effect" takes place: any further increase in economic complexity reduces the level of environmental degradation due to increasing technological efficiency resulting in less pollutants and material intensity of the production process (Neagu, 2019).

Using the longitudinal ECI and carbon emission data of countries in the OECD, Dogan and Inglesi-Lotz (2020) I confirmed the EKC trend, wherein an increase in ECI is associated with higher levels of emissions in low and high middle-income countries and lower levels of emissions in high-income countries. Other empirical studies have also provided evidence of the technological effect of the EKC in high-income countries. All 28 countries in the EU are likely to be in the latter phase of the EKC, where an increase in ECI leads to a decrease in



Source(s): Author's own creation/work

Figure 2. Economic complexity and environmental degradation in the environmental Kuznets curve

carbon emissions (Boleti *et al.*, 2021; Can and Gozgor, 2017; Chu and Le, 2021; Doğan *et al.*, 2022; Neagu, 2019). In the study by Dogan and Inglesi-Lotz (2020), high-income countries were defined as those with GDP per capita $12,476 or more in 2010, which applied to all EU-28 countries. Nevertheless, the economic development levels of the countries and regions in the EU differ significantly.

H4. European SMEs in a country with high economic complexity are likely to adopt proactive-EIs.

3.3.2 Trade openness. An exchange of goods and services between countries through trade provides opportunities for SMEs to absorb external knowledge and skills. The environmental consequences of trade openness (TO) can be assessed via three different channels: scale effect, composition effect and technique effect. The scale effect describes the negative impact of trade on environmental pressures, which results from intensified industrial activity and increased pollution. The composition effect takes the perspective of the global value chain where countries are specialized in the industries in which they have a comparative advantage. Under this scenario, the environmental impact of TO may be positive or negative depending on the energy or pollution intensity of the industry. Finally, the technique effect describes the positive effects of trade on environmental considering that trade liberalization accelerates technological dissemination and the adoption of efficient practices (Grossman and Krueger, 1991). Trade can positively influence a firm's environmental performance by exposing the firm to new technologies, knowledge, regulations and cultures (Tachie *et al.*, 2020).

Empirical studies have shown that in high-income countries, the technique effect has the greatest impact. Studies which included both high-income and low-income countries reported that TO resulted in reduced carbon emissions or energy consumption in high-income countries, while the opposite was observed in low-income countries; this may be due to the scale effect and the increases associated with the EKC (Doğan *et al.*, 2019, 2022; Dou *et al.*, 2021; Sun *et al.*, 2019). The effects seen in high-income countries were observed across Europe; Tachie *et al.* (2020) confirmed the long-term relationship between TO and per capita carbon emission reduction. Two potential factors were reported to be behind these results: most

European countries are making efforts to reduce pollution levels and comply with environmental standards, while others are in the course of changing from emerging economies dominated by polluting industries to post-industrial economies.

H5. European SMEs in a country with high trade openness are likely to adopt proactive-EIs.

3.3.3 Public investment in green R&D. Endogenous knowledge stocks generated within countries can facilitate knowledge spillovers, and SMEs can exploit dynamic efficiency to adopt these knowledge stocks. Public R&D investments are more important for EIs than private R&D investments because governments tend to have a greater willingness to invest in radical innovations (Orlando *et al.*, 2022). For example, governments may support the production of green patents and encourage firms to implement EI activities by standardizing knowledge, concepts, practices and objectives (de Jesus and Mendonça, 2018; Kivimaa and Kern, 2016; Orsatti, 2019). This approach is especially important for SMEs, as they often find it difficult to implement sustainability measures due to a lack of resources (Del Brío and Junquera, 2003; Revell *et al.*, 2010). Countries that allocate resources towards improving the effectiveness of green R&D would need to address the crowding-out effect of EIs in comparison to other innovations (Rennings, 2000). R&D programmes tailored to the CE can be especially effective for proactive-EIs, as these efforts would encourage the development of new technologies and business models (Veugelers, 2012).

Empirical studies on the relationship of public R&D investment and EU SMEs have shown that public funding has a positive effect on the probability of developing EIs even accounting for effects of other policy instruments such as demand-pull policies and regulatory incentives (Cecere *et al.*, 2020). Brogi and Menichini (2021) found that EU funding programmes could help reduce the financial constraints that SMEs face when developing EIs. Authors have also indicated the positive effect of public environmental and energy R&D (PEERD) on adoption of proactive-EI; Garrido-Prada *et al.* (2021) found that the higher the rate of PEERD of a European country, the more SMEs there will be in participating in circular economic activities, while Ren and Albrecht (2023) demonstrated that when compared to the role of demand-pull policy, PEERD is effective in promoting SMEs to undertake EIs that have higher costs such as re-planning and redesigning activities.

H6. European SMEs in a country with a high green R&D investment rate are likely to adopt proactive-EIs.

4. Methodology

4.1 Data description and methodology

We assessed the hypotheses regarding national contexts that facilitate SMEs' adoption of proactive-EIs by comparing the influence of country-level factors. Data from the Eurobarometer 498 survey "Small and Medium-Sized Enterprises, Resource Efficiency and Green Markets Survey" conducted in 2021 formed the basis for testing the indicators in the MLP framework. The sample used in the Eurobarometer survey was representative of each country's population and was acquired through a multistage random sampling [1] process, thus providing an adequate basis to assess various national contexts. Of the SMEs surveyed in Eurobarometer 498, a subset of 6,188 SMEs in resource-intensive sectors was considered in the present study.

A binary logistic regression (BLR) analysis, which has been used in several empirical studies on EI (Adeyeye *et al.*, 2016; Kalar *et al.*, 2021; Zhang *et al.*, 2018), was conducted to assess the hypotheses. With a BLR, we can determine the effect that multiple independent variables have on the log odds of the dependent variable (Ghazilla *et al.*, 2015; Oluwadmu and

Kayode, 2008), which allowed us to answer the binary classification problems in our study; specifically to capture whether SMEs will adopt proactive-EIs or not. Other comparable methodologies, for example linear models where its dependent variable is a continuous numerical variable were not appropriate in this regard. Furthermore, while other multivariate analyses such as discriminant analysis also capture categorical dependent variables, logistic regression was more suitable for this study because it does not require meeting the assumptions of multivariate normality and equal variance-covariance matrices across groups (Hair *et al.*, 2010).

The BLR used in this study is given in E1.

4.1.1 E1: BLR.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots + \beta_i X_i + \mu$$

Here, β ($i = 1, 2, \ldots, 6$) are regression coefficients, α is the intercept parameter and μ is the random interference. $Y = 1$ indicates the implementation of proactive-EI actions and $Y = 0$ indicates otherwise. The equation demonstrates that a variable Xi with coefficient $\beta i >$ 0 increases the SMEs' log odds of implementing proactive-EIs by βi, which otherwise decreases. To show what the odds ratio (OR) is, the BLR was rewritten as the following equation (E2).

4.1.2 E2: odds ratio of BLR.

$$\mathrm{Ln}\,(p/1 - p) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots + \beta_i X_i + \mu$$

Here, Ln (p/1−p) represents the log odds of SMEs adopting proactive-EIs; X ($i = 1, 2, \ldots, 9$) is a series of knowledge-related determinants and firm characteristics represented as independent and control variables, respectively. Each Xi's impact on SMEs' willingness to adopt proactive-EIs is comparable because their beta coefficients can be directly exponentiated through e^βi. This then gives the normal odds increase that a one unit increase in Xi would yield to Y. The details of these variables are listed in Table 1.

The dependent variables were the proactive-EI actions measured in the Eurobarometer survey, while the independent variables which assessed the contribution of each determinant (micro, meso and macro) were obtained from relevant country-level data published in 2021 or the closest old year to 2021, when the Eurobarometer 498 survey was conducted. The BLR model controlled for several firm characteristics that may influence SMEs' need and ability to adopt proactive-EIs. First, size was controlled for using a variable based on the natural logarithm of the number of employees considering that large firms could be expected to have more resources for proactive measures (Kesidou *et al.*, 2012). Second, firm age was controlled for, considering that older firms would have more experience and resources to facilitate the adoption of proactive-EIs than young firms (Cainelli *et al.*, 2015). Finally, firms' market segments, consumers, companies and public administration were controlled for using three dichotomous nonexclusive variables.

5. Results

5.1 Descriptive statistics

Table 2 presents the summary statistics of the variables. Among the 6,188 SMEs, 73.5% adopted proactive-EIs and 90.2% adopted reactive-EIs. Selling residues and wastes to other companies (SRW) had the highest rate of the SMEs' adoption among the proactive-EI actions surveyed at a rate of 42%, while the predominant use of renewable energy (URE) had the lowest adoption rate at 23.5%. The remaining two proactive-EIs were for switching to greener suppliers of materials (SGS), which had a rate of 36.1% and for designing products that are easier to maintain, repair and reuse (DPEM), which had a rate of 33.6%.

Table 1. Definitions of the variables

Variables				Description	Source
Resource intensive industries by NACE category		(B) Mining and quarrying, (C) manufacturing, (D) electricity, gas, steam and air conditioning supply, (E) water supply; sewerage, waste management and remediation activities, (F) construction			
Dependent variables		Y_ProactiveEI		A binary variable taking a value 1 if a firm has reported to be either doing one of the following actions	Eurobarometer 498
			Y_SGS	Switching to greener suppliers of materials	
			Y_DPEM	Design products that are easier to maintain, repair or reuse	
			Y_URE	Using predominantly renewable energies (including own production through solar panels)	
			Y_SRW	Selling your residues and waste to another company	
		Y_ReactiveEI		A binary variable taking a value 1 if a firm has reported to be either: - saving water, energy, or materials - minimizing waste - recycling, by reusing material or waste within the company	
Independent variables	Micro	X_Awareness		% of citizens which have "Bought products marked with an environmental label" in the past six months in 2019	Eurobarometer 501
	Meso	X_Collaboration		% of Product and/or process innovative SMEs engaged in co-operation in 2016	Eurostat
		X_ Agglomeration		GDP share (%) of resource intensive sector's (industry and construction) in the total GDP in 2021*	Eurostat
	Macro	X_ECI		Economic Complexity Index of 2020	Atlas of economic complexity
		X-TradeOpn		% if sum of import and export in the total GDP in 2021	Worldbank
		X_R&D		Average % of sum of relevant public R&D expenditures (environmental, industrial, and energy) to eco-innovation over 5 years (2017–21)	Eurostat
			X_ EnvR&D	Average % of environmental R&D within the total R&D over 5 years (2017–21)	
			X_ IndR&D	Average % of industria R&D within the total R&D over 5 years (2017–21)	
			X_ EngR&D	Average % of energy R&D within the total R&D over 5 years (2017–21)	

(*continued*)

Variables			Description	Source
Resource intensive industries by NACE category		(B) Mining and quarrying, (C) manufacturing, (D) electricity, gas, steam and air conditioning supply, (E) water supply; sewerage, waste management and remediation activities, (F) construction		
Control variables	Firm characteristics	C_FirmSize	Number of employees in log scale	Eurobarometer 498
		C_FirmAge	Number of years since a firm's establishment	
		C_B2C	A binary variable taking a value 1 if a firm sold its product or services to a consumer	
		C_B2B	A binary variable taking a value 1 if a firm sold its product or services to a company	
		C_B2PA	A binary variable taking a value 1 if a firm sold its product or services to public administrations	

Note(s): For UK, data of 2019 was used
ECI was not available for Luxembourg and Malta
Source(s): Author's own creation/work

Table 1.

Continuous variables (N = 6,188)				Mean	SD
Independent variables	Micro	X_Awareness (%)		23.0%	12.9%
	Meso	X_Collaboration (%)		25.9%	7.1%
		X_Agglomeration(%)		26.0%	5.5%
	Macro	X_ECI		1.17	0.41
		X-TradeOpn (%)		122.65%	53.33
		X_R&D (%)		15.7%	7.5%
			X_EnvR&D (%)	2.6%	1.7%
			X_IndR&D (%)	10.2%	7.1%
			X_EngR&D (%)	2.9%	1.9%
Control variables	Firm characteristics	C_FirmSize		1.32	0.68
		C_FirmAge		28.88	27.06
Rate of adoption of binary variables (N = 6,188), %					
Dependent variables		Y_ProactiveEI		73.5%	
			Y_SGS	36.1%	
			Y_DPEM	33.6%	
			Y_URE	23.8%	
			Y_SRW	42.2%	
		Y_Reactive		90.2%	
Control variables	Firm characteristics	C_B2C		53.6%	
		C_B2B		80.3%	
		C_B2PA		29.3%	

Note(s): SGS = switching to greener suppliers of materials; DPEM = designing products that are easier to maintain, repair, and reuse; URE = predominant use of renewable energy; SRW = selling residues and wastes to other companies
Source(s): Author's own creation/work

Table 2.
Descriptive statistics

Table 3 presents the country-level data for each variable, disaggregated by old and new member states. Countries with the highest rates of proactive-EI adoption were Sweden (91%), Belgium (91%) and Spain (88%), while countries with the lowest ratings for proactive-EIs were Bulgaria (50.9%), Ireland (52.9%) and Denmark (59.4%). EU-15 countries, which were member states present before the 2004 enlargement, were grouped for analysis with the EU-13 countries, which have on average lower economic development rates and, therefore, were expected to have low adoption rates for proactive-EIs. On average, the EU-15 (76%) countries performed better than the EU-13 (69%) countries, particularly northern countries like Sweden, but there were underperformers and overperformers in each group: the underperformers for proactive-EIs among the EU-15 countries and included Ireland (53%), Denmark (59%) and France (63%) and the overperformers among EU-13 countries and included Romania (83%), Slovenia (77%) and Slovakia (77%). The adoption rate of individual proactive-EI actions, SGS, DPEM, URE and SRW are provided on the right column of Table 3.

The mean rate of citizens that bought products marked with an environmental label, a micro-level determinant, was 23.0%. Two countries with comparably high awareness rates (Sweden: 64.8%, Denmark: 51.1%) contributed to a relatively high standard deviation of 12.9%. The mean of two meso-level determinants, namely (1) the rate of SMEs collaborating with external partners for innovation activities and (2) intra-industry agglomeration measured by the sum share of the resource-intensive sector's (industry and construction) GDP, was around 26.0%. Most countries' collaboration rates were around the mean value; only a few were substantially high (Cyprus 42.6%, Finland 40.8%, Ireland 40.2%) or low

Table 3. Country-level data

			Dependent variables						Independent variables										
									Micro	Meso		Macro							
EU category	Isocntry	Country full name	Y_ Proactive EI (=1)	Y_ SGS(=1)	Y_ DPEM (=1)	Y_ URE (=1)	Y_ SRW(=1)	Y_ ReactiveEI (E = 1)	X_ awareness	X_ Collaboration	X_ Agglomeration	X_ Industry	X_ Construction	X_ ECI	X- TradeOpn	X_ R&D	X_ EnvR&D	X_ EngR&D	X_ IndR&D
EU15			0.759	0.392	0.345	0.286	0.397	0.909	0.274	#N/A	0.238	0.184	0.054	#N/A	123.149	0.172	0.023	0.032	0.116
EU15	AT	Austria	0.767	0.262	0.267	0.302	0.287	0.941	0.317	0.281	0.286	0.214	0.072	1.696	110.990	0.174	0.011	0.028	0.136
EU15	BE	Belgium	0.909	0.514	0.432	0.519	0.601	0.959	0.180	0.345	0.232	0.179	0.053	1.133	169.370	0.378	0.010	0.016	0.352
EU15	DK	Denmark	0.594	0.245	0.258	0.279	0.319	0.782	0.511	0.255	0.222	0.167	0.056	1.119	112.430	0.126	0.011	0.037	0.077
EU15	FI	Finland	0.762	0.377	0.377	0.303	0.437	0.926	0.353	0.408	0.284	0.206	0.077	1.402	77.630	0.255	0.026	0.029	0.200
EU15	FR	France	0.630	0.285	0.350	0.093	0.402	0.858	0.270	0.290	0.188	0.131	0.057	1.288	61.970	0.118	0.020	0.088	0.010
EU15	DE	Germany	0.735	0.342	0.255	0.378	0.398	0.842	0.280	0.200	0.296	0.240	0.055	1.961	89.390	0.208	0.028	0.054	0.126
EU15	GR	Greece	0.768	0.439	0.398	0.183	0.476	0.886	0.142	0.268	0.183	0.163	0.019	0.247	89.180	0.203	0.048	0.036	0.119
EU15	IE	Ireland	0.529	0.312	0.165	0.135	0.094	0.876	0.204	0.402	0.401	0.380	0.022	1.348	229.400	0.235	0.020	0.011	0.204
EU15	IT	Italy	0.771	0.337	0.247	0.301	0.240	0.968	0.132	0.238	0.252	0.203	0.049	1.335	63.060	0.172	0.026	0.033	0.113
EU15	LU	Luxembourg	0.841	0.571	0.413	0.159	0.429	0.873	0.324	#N/A	0.125	0.062	0.064	#N/A	388.850	0.142	0.025	0.002	0.116
EU15	NL	Netherlands	0.876	0.388	0.438	0.533	0.529	0.938	0.312	0.327	0.203	0.150	0.053	0.986	156.190	0.096	0.007	0.031	0.058
EU15	PT	Portugal	0.637	0.200	0.188	0.135	0.331	0.890	0.105	0.131	0.223	0.173	0.050	0.758	87.050	0.112	0.043	0.021	0.048
EU15	ES	Spain	0.882	0.525	0.412	0.239	0.588	0.980	0.124	0.225	0.227	0.169	0.057	0.766	68.330	0.152	0.035	0.025	0.092
EU15	SE	Sweden	0.913	0.555	0.545	0.472	0.488	0.970	0.648	0.235	0.255	0.188	0.067	1.593	88.160	0.096	0.017	0.043	0.036
EU15	GB	United Kingdom	0.774	0.522	0.430	0.257	0.343	0.948	0.215	#N/A	0.200	0.134	0.066	1.540	55.240	0.109	0.022	0.033	0.054
EU13			0.693	0.326	0.310	0.177	0.421	0.883	0.176	0.252	0.269	0.208	0.061	#N/A	152.295	0.129	0.026	0.020	0.083
EU13	BG	Bulgaria	0.509	0.117	0.126	0.099	0.369	0.770	0.098	0.209	0.265	0.221	0.044	0.632	124.990	0.092	0.004	0.005	0.083
EU13	HR	Croatia	0.712	0.293	0.275	0.140	0.514	0.946	0.197	0.229	0.249	0.189	0.060	0.800	103.760	0.042	0.007	0.004	0.032
EU13	CY	Cyprus	0.621	0.326	0.211	0.253	0.295	0.874	0.204	0.426	0.146	0.085	0.061	0.422	160.940	0.009	0.009	0.000	0.000
EU13	CZ	Czech	0.787	0.320	0.406	0.172	0.549	0.930	0.200	0.262	0.333	0.277	0.056	1.780	142.110	0.175	0.021	0.045	0.110
EU13	EE	Estonia	0.606	0.225	0.250	0.157	0.394	0.826	0.194	0.344	0.264	0.197	0.067	0.986	160.790	0.077	0.011	0.001	0.064
EU13	HU	Hungary	0.728	0.316	0.377	0.268	0.447	0.930	0.120	0.314	0.311	0.246	0.065	1.542	161.910	0.286	0.034	0.040	0.211
EU13	LV	Latvia	0.599	0.263	0.306	0.095	0.306	0.806	0.197	0.198	0.227	0.165	0.061	0.708	130.220	0.190	0.061	0.032	0.097
EU13	LT	Lithuania	0.726	0.358	0.382	0.151	0.467	0.939	0.203	0.279	0.287	0.216	0.070	0.855	156.570	0.123	0.001	0.032	0.090
EU13	MT	Malta	0.685	0.370	0.274	0.315	0.192	0.822	0.168	0.210	0.141	0.098	0.043	#N/A	283.470	0.049	0.008	0.003	0.039
EU13	PL	Poland	0.669	0.319	0.250	0.154	0.400	0.885	0.175	0.200	0.335	0.269	0.067	1.016	117.620	0.103	0.036	0.006	0.061
EU13	RO	Romania	0.826	0.483	0.431	0.149	0.566	0.924	0.132	0.144	0.308	0.235	0.073	1.274	87.360	0.191	0.058	0.037	0.097
EU13	SK	Slovakia	0.767	0.410	0.414	0.110	0.427	0.947	0.173	0.215	0.308	0.249	0.059	1.430	188.360	0.121	0.028	0.013	0.080
EU13	SI	Slovenia	0.775	0.441	0.329	0.243	0.550	0.878	0.223	0.244	0.324	0.263	0.062	1.540	161.740	0.215	0.055	0.044	0.115

Note(s): SGS = switching to greener suppliers of materials; DPEM = designing products that are easier to maintain, repair, and reuse; URE = predominant use of renewable energy; SRW = selling residues and wastes to other companies
Source(s): Author's own creation/work

(Portugal 13.1%, Romania 14.4%). Similarly, the GDP shares of some countries' resource-intensive sectors were substantially high (Ireland 40.1%) or low (Portugal 12.5%, Malta 14.1%, Cyprus 14.6%).

All macro-level determinants showed a degree of deviation across countries. The mean share of government R&D investment relevant to proactive-EI (energy, environment and industry) between 2017 and 2021 was 15.7%. Among these relevant R&D types, industrial R&D had a high share of 10.2% when compared to environmental and energy R&D, which were both close to 3%. Some countries had substantially high R&D shares (Belgium 37.8%, Hungary 28.6%, Finland 25.5%), while others had substantially low shares (Cyprus 0.9%, Croatia 4.2%, Malta 4.9%). The mean ECI of the EU countries was 1.17, which was substantially higher than the global mean of 0.01, indicating that, on average, European countries have high levels of multifaced technological capabilities. However, there were disparities among the EU countries; the highest ECIs were found in Germany (1.96), Czechia (1.78) and Austria (1.70), while the lowest scores were found in Greece (0.25), Cyprus (0.42) and Bulgaria (0.632). The mean rate of trade openness, represented as the sum share of exports and imports in the GDP, was 122.7%. Substantial differences in trade openness were seen between the highest (Luxembourg 388.9%, Malta 283.5%, Ireland 229.4%) and lowest (UK 55.2%, France 62.0%, Italy 63.1%) rates.

5.2 Analysis

Table 4 presents the correlation matrix of the variables. All correlation figures were between -0.50 and 0.50, except for the ECI and agglomeration (0.585), indicating that the concern for multicollinearity was minimal.

The BLR results and a list of the hypotheses and their outcomes are presented in Tables 5 and 6, respectively. The goodness of fit represented by Nagelkerke R^2 was 6.2% for the analysis involving proactive-EIs (2.6% for DPEM, 4.1% for GSM, 10.2% for URE, 9.0% for SRW) and 4.6% for reactive-EIs. The positive influence of the micro-level determinant for H1, namely individual environmental awareness, was supported ($\beta = 0.72; p < 0.05$) in the overall analysis of proactive-EI actions as well as individual proactive-EI actions. The posited positive effects of the meso-level determinants associated with H2 and H3, namely external collaboration and sector agglomeration, respectively, were not supported (H2: $\beta = -1.30$, $p < 0.05$; H3: $\beta = -2.5, p < 0.01$). However, each individual proactive-EI action had a different association with the meso-level determinants: GSM and external collaboration as well as SRW and agglomeration had nonsignificant associations, while URE and collaboration had a positive association.

Among the macro-level determinants, the positive influence of ECI and R&D stated in H4 and H6 were supported to a moderate degree while that of TO in H5 was not supported (H4: $\beta = 0.36, p < 0.05$; H5: $\beta = -0.001, p > 0.05$; H6: $\beta = 2.7, p < 0.01$). The association between macro-level determinants and each proactive-EI action held the same in the sub-analysis with the exception of influence of R&D on URE rejecting the H6 and ECI on SRW not supporting the H4. When considering reactive-EIs, apart from a positive association with the ECI, dissimilar associations with the determinants were found. TO was found to be negatively associated with reactive-EIs, while the remaining determinants – environmental awareness, R&D, external collaboration and agglomeration – were nonsignificant.

6. Discussion

Encouraging firms to adopt EIs and inducing green entrepreneurship are important areas of focus in the EU, where SMEs significantly contribute to the production of pollution and waste. In this study, the NISs of countries in the EU were assessed using an MLP framework

Table 4. Correlations and discriminant validity

X_Awareness	X_Awareness	X_Collaboration	X_Agglomeration	X_ECI	X_TradeOpn	X_RD	X_FirmSize	C_FirmAge
X_Awareness	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X_Collaboration	0.182	1.000	0.000	0.000	0.000	0.000	0.000	0.000
X_Agglomeration	−0.117	−0.046	1.000	0.000	0.000	0.000	0.000	0.000
X_ECI	0.376	0.061	0.585	1.000	0.000	0.000	0.000	0.000
X_TradeOpn	−0.152	0.403	0.417	0.073	1.000	0.000	0.000	0.000
X_RD	−0.176	0.265	0.245	0.303	0.166	1.000	0.000	0.000
C_FirmSize	0.015	−0.016	−0.042	0.025	−0.030	−0.005	1.000	0.000
C_FirmAge	0.177	0.095	−0.128	0.058	−0.046	0.015	0.363	1.000

Source(s): Author’s own creation/work

Table 5.
Determinants of external knowledge absorption for proactive-EIs in SMEs: Results of a binary logistic regression

	Y_ProactiveEI	p	Y_SGS	p	Y_DPEM	p	Y_URE	p	Y_SRW	p	Y_ReactiveEI	p
(Intercept)	0.01713	NS	−2.09577	***	−1.40956	***	−1.58025	***	−1.49514	***	0.32617	NS
X_Awareness	0.72077	**	1.25267	***	1.43182	***	1.10676	***	0.01162	NS	−0.69375	NS
X_Collaboration	−1.3034	**	0.17816	NS	−0.402	***	1.83803	***	−1.35033	**	1.27057	NS
X_Agglomeration	−2.49928	***	−0.34962	NS	−3.11998	***	−9.10549	***	−0.7318	NS	1.03617	NS
X_ECI	0.36213	***	0.02001	NS	0.28029	***	1.38936	***	0.03034	NS	0.3681	**
X_TradeOpn	−0.00052	NS	−0.00074	NS	0.00133	NS	0.00073	NS	0.00065	NS	−0.00357	**
X_R&D	2.7036	***	NA	NS	NA	NS	NA	NS	NA	NS	0.82616	NS
X_INDrd	NA	NS	2.1387	***	1.44143	NS	NA	NS	1.14457	**	NA	NS
X_Envrd	NA	NS	12.00518	***	7.92964	NS	NA	NS	3.43775	’*	NA	NS
X_ENGrd	NA	NS	NA	NS	NA	***	−13.94729	***	NA	NS	NA	NS
C_FirmSize	0.45645	***	0.27646	***	0.09509	***	0.41941	***	0.60145	***	0.46024	***
C_FirmAge	0.0023	NS	0.00321	***	−0.00117	**	0.00355	***	0.00413	***	0.00794	***
C_B2C1	0.12146	’*	0.18659	***	0.16978	***	−0.06044	NS	−0.00751	NS	0.40443	***
C_B2B1	0.45979	***	0.20079	**	0.37925	NS	0.0772	NS	0.64961	***	0.53641	***
C_B2PA1	0.02195	NS	0.1732	***	−0.07768	**	0.08329	NS	0.01505	NS	−0.17236	’*
nagelkerke r2	0.06153	NS	0.04109	NS	0.02608	NS	0.10244	NS	0.08962	NS	0.04621	NS

Note(s): * Significance at 0.1 level
** Significance at 0.05 level
*** Significance at 0.01 level
NS, Not significant
SGS = switching to greener suppliers of materials; DPEM = designing products that are easier to maintain, repair, and reuse; URE = predominant use of renewable energy; SRW = selling residues and wastes to other companies
Source(s): Author’s own creation/work

Hypotheses		Outcome
H1	European SMEs in a country with high environmental awareness are likely to adopt proactive-EIs	Supported
H2	European SMEs in countries that have a high rate of collaboration with other firms and entities for innovative activities are likely to adopt proactive-EIs	Rejected
H3	European SMEs operating in countries where resource-intensive sectors have high economic shares are likely to adopt proactive-EIs	Rejected
H4	European SMEs in a country with high economic complexity are likely to adopt proactive-EIs	Supported
H5	European SMEs in a country with high trade openness are more likely to adopt proactive-EIs	Not supported
H6	European SMEs in a country with a high green R&D investment rate are likely to adopt proactive-EIs	Supported

Source(s): Author's own creation/work

Table 6. Outcomes of the hypotheses

to capture the determinants of external knowledge absorption in SMEs' adoption of proactive-EIs. The results showed that, along with TO, certain knowledge-related factors significantly influenced firms' adoption of proactive-EIs. One micro-level factor, namely public environmental awareness and two macro-level factors, namely economic complexity and government R&D, positively influenced SMEs' willingness to adopt proactive-EIs, whereas two meso-level factors, namely sector agglomeration and external collaboration, were found to have a negative influence.

6.1 Theoretical contributions

With the aim of proposing ways for countries to effectively transition to a CE, this study focused on proactive-EIs because they occur beyond the limit of a firm's organizational boundary and are more relevant to the context of a CE than reactive-EIs. The determinants were assessed from an NIS perspective, which views EIs as resulting from dynamic processes that involve different levels of actors and interactions in a country. To assess country-level differences in a systemic manner, an MLP framework encompassing the macro-, meso- and micro-levels of the economy was used. The MLP framework allowed for assessing dimensions not explored in extant empirical studies on European green entrepreneurship: environmental awareness and external collaboration. Furthermore, considering the findings of Garrido-Prada *et al.*'s (2021) study, which verified that energy and environmental R&D positively affects SMEs' undertaking of CE activities, we included industrial R&D as a relevant government investment in our assessment of government R&D. We believe that its inclusion adequately reflected the government investment related to proactive-EI, since industrial R&D includes activities such as recycling waste as well as improving process efficiency.

A growing number of studies on EI have been published since 2008 (Bossle *et al.*, 2016), particularly in the EU. Several empirical studies were published after the Eurobarometer survey started a series on resource efficiency and SMEs in 2012, as well as CE and SMEs in 2016. Some studies have investigated the drivers of SMEs' environmental initiatives based on technology push, demand pull, or the provision of regulatory or financial instruments (Aristei and Gallo, 2021; Bassi and Guidolin, 2021; Cainelli *et al.*, 2020; Demirel and Danisman, 2019; Özbuğday *et al.*, 2020). Others have assessed the differences between drivers based on the type of EI action (Hoogendoorn *et al.*, 2015; Triguero *et al.*, 2014, 2022). Despite the breadth of these studies, the heterogeneity of EU member states has not yet been explored apart from a focus on certain aspects such as government R&D investment (Garrido-Prada *et al.*, 2021) or environmental policy (Cariola *et al.*, 2020; Hoogendoorn *et al.*, 2015), although European empirical studies have indicated the importance of accounting for heterogeneity across EU countries (Bassi and Dias, 2020; García-Quevedo *et al.*, 2020).

6.2 Implications for policymakers and managers

Our results led to the identification of important leverage points for policymakers. First, at the micro-level, the positive association between an individual's environmental literacy – measured by buying products marked with an environmental label – and proactive-EI is supported by the findings of Lehmann *et al.* (2022), which suggest that, rather than a mere increase in average school years, providing specific education about environmental issues is essential for promoting circularity.

The findings also indicate the existence of coordination failure for knowledge transfer at the meso level. Agglomeration, measured in the size of the industrial sector was shown to negatively predict the adoption of proactive-EIs; this can be explained by prospect theory, according to which proactive-EIs are less favourable in the dominant sectors of countries with high sectoral agglomeration than in the lagging sectors, because the former may lose more by altering business practices (Garrido-Prada *et al.*, 2021). Dominant sectors tend to be reluctant to adopt EIs, and their strong positions in the market could hamper new entrants as well (Grubb *et al.*, 2015). Therefore, it is important for policymakers to provide incentives for dominant sectors to take the risk of changing their business models. Further, the findings regarding the negative influence of external collaboration on EI adoption indicate that existing collaborative activities might strengthen current business practices, thus discouraging the exploration or adoption of EIs. Therefore, tailored measures to guide collaborations towards EI and to facilitate knowledge transfers, such as direct financing via subsidies, grants to mission-oriented collaborative projects, or the provision of soft instruments such as networking opportunities or outreach activities, should be included in policy.

The macro-level determinants of knowledge generation had dissimilar outcomes. The positive influence of ECI indicates the importance of nurturing versatile technical skill sets to promote green innovation in a country. In contrast, TO did not have a significant influence on SMEs' adoption of proactive-EIs in the present study, despite previous studies demonstrating its positive associations with carbon emission and energy consumption reductions in high-income countries due to the technique effect. It is possible that the technique effect of trade driven by global demand incentivizes large companies to adopt green technologies and practices but is less impactful with SMEs which contribute to a smaller share of global transactions. In addition, while the reduction of carbon emissions and energy consumption may be based on a global framework, developing waste reduction and recycling infrastructure would depend more on the initiatives of individual countries, leading to the limited effect of TO on changing the behaviours of SMEs that produce a lot of waste. Regarding government R&D, both environmental and industrial R&D positively influenced the relevant proactive-EI actions measured, indicating that the upstream knowledge generated to control pollution and improve industrial efficiency can encourage green entrepreneurship actions. Countries with high levels of energy R&D had lower rates of renewable energy adoption among SMEs. Some of this is likely because countries with high energy R&D levels are large producers of fossil fuels, but it also reflects an opportunity for price-based (e.g. feed-in tariffs) or quota-based (e.g. green certificates) measures to induce demand.

6.3 Limitations and future research

This study was not free of limitations, and the results present opportunities for future research. First, the cross-sectional dataset used was restricted in its ability to capture trends. The Eurobarometer survey on the resource efficiency of SMEs was conducted in a series in

2014, 2018 and 2021; future studies could make use of this longitudinal data to capture trends. Second, the ability of the selected data to precisely measure the hypothesized variables was limited, as each hypothesis had to be analysed using the available datasets for each EU member state. For example, the environmental awareness levels of individuals were assessed based on consumers' purchases of an eco-labelled product in the previous six months. Third, the intragovernmental funds of the EU are distributed to member states for environmental projects and SME support, and the redistribution of funds from the European Regional Development Fund and Cohesion Fund for environmental purposes may affect EI adoption rates in member states; this was not captured in the present study. Future research could assess each of the micro-, meso- and macro-mechanisms with refined local data to validate the findings. Finally, based on the NIS approach, SMEs' knowledge absorption was considered to occur at the country level. Although the heterogeneity of European member states was a unit of analysis, country-level differences only account for a part of all differences, and other perspectives that focus on regional and sectoral characteristics should be considered in future research to obtain a more comprehensive understanding.

Note

1. https://www.gesis.org/en/eurobarometer-data-service/survey-series/standard-special-eb/sampling-and-fieldwork

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Corresponding author
Miyana Yoshino can be contacted at: miyanaxx@gmail.com