



Research article

Commitment of European SMEs to resource efficiency actions to achieve sustainability transition. A feasible reality or an elusive goal?

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ABSTRACT

The European Union has built an interdependent framework to promote sustainability transition through commitment in resource efficiency (RE) actions as echoed in the European Green Deal. Although the factors affecting firms' decision to adopt a green strategy have been extensively explored, those affecting commitment remain unexplored. Thus, we study whether commitment of European SMEs to RE actions fosters sustainability transition and, what drives such commitment. Data includes more than 37,000 European SMEs from 2013 through 2017, combined with country-specific characteristics explored via a probit model with sample selection. Findings indicate that during the study period there has been a change in the structure of incentives of the firms, as in the beginning of the period, adoption of RE actions and future engagement were considered as independent decisions. We document that commitment is driven RE enhancers such as the implementation of new technological paradigms, cooperation, and specialized business advice while resource productivity, green energy, and competitiveness further foster commitment. Findings advocate that commitment in RE actions to achieve sustainability transition is a feasible reality. Efforts of policymakers should focus on further enabling RE committed firms by reducing policy red tape.

1. Introduction & motivation

The launch of the European Green Deal (European Commission, COM/2019/640) is the capstone of a long-term commitment of the European Union (EU) to develop a solid and coherent framework to promote sustainability transition through Resource Efficiency (RE). Sustainability transition within the European Union is conceptualized as achieving Net-Zero targets by 2050 through economic and societal transformations carried out by all sectors in the economy and society (European Commission, COM/2018/773-b). Over the past twenty years, the EU has been connecting the dots towards sustainable growth through a mosaic of policy directives. These include the (i) Thematic Strategy focusing on the efficient use of natural resources to ensure well-being (European Commission, COM/2005/0670), (ii) the Europe 2020 strategy setting ambitious goals for sustainable and inclusive growth (European Commission, COM/2010/2020), (iii) the Resource

Efficiency Flagship Initiative, within the Europe 2020 strategy, providing a long-term framework for actions fostering sustainable growth (European Commission, COM/2011/0571-b), (iv) the Eco-Innovation Action Plan targeting in reducing the environmental impacts of production through innovation (European Commission, COM/2011/0899-a), (v) the Strategy for a Climate Change Policy re-arranging energy sources to secure environmental quality (European Commission, COM/2015/080-b), (vi) the Circular Economy Action Plans promoting sustainability transition through circular economy to reduce pressure on natural resources and at the same time to boost employment (European Commission, COM/2015/614-a; COM/2018/028-d; COM/2020/98-b), (vii) and the European strategic long-term vision for a climate neutral economy to facilitate the transition to a climate-neutral society (European Commission, COM/2018/773-b). The above, along with a stream of Renewable Energy Directives constituting a legal framework to commit member states

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using green energy to achieve sustainability targets (2009/28/EC-b; 2018/2001/EU-a; COM/2021/557-a) are the cornerstones mobilizing long-term commitment.

Along with the above directives focusing on the country-level, achieving sustainability transition requires long-term commitments and actions from multiple productive layers of society, perhaps none more critical than Small and Medium Enterprises (SMEs). A transition is long-term process of radical and structural change of a system irrespective of the aggregation level, i.e., firm, industry, sector, region, or country. According to Grin et al. (2010) sustainability transition is defined as a “radical transformation towards a sustainable society, as a response to a number of persistent problems confronting contemporary modern societies”. In the case of a firm, sustainability transition refers to implementing a business agenda with no negative footprint either on the environmental or on the society, aspects that are included in the concept of sustainability (United Nations, 2022).

The conceptual approach introduced herein draws upon the socio-technical transition which, besides the technological aspect, requires changes in the business model (Geels, 2018; Geels and Schot, 2010; Grin et al., 2010) as well. In this paper, sustainability transition is traced by the willingness to commit in RE actions in the future, given already implementing RE actions, facilitated by a set of RE enhancers. In the socio-technical transition context, an enhancer could be identified as a means that would support SMEs to achieve sustainability transition and could take the form of either integrating new technological paradigms, funding related aspects, collaboration and networking building or a well-structured regulatory framework, among others.

Thus, any business strategy that has either an environmental, social, cultural, or economic impact or a combination of the above during the decision-making process is sustainability-enhancing. Therefore, sustainability transition in business could be considered as a forward-looking dynamic process including radical transformation of societal systems such as socio-technical regimes, towards more sustainable modes of production and consumption (European Commission, 2020-d; Markard et al., 2012; Smith et al., 2010). Admittedly, SMEs improving their RE in production is one of the cruxes in achieving sustainability transition (Fresner, 2010).

European SMEs are one of the major employers employing 66% of the EU's total workforce (Južnik Rotar et al., 2019) and produce around 75% of the total industrial output (Fresner, 2010). On the other hand, SMEs are responsible for 60–70% of all industrial pollution in Europe (OECD, 2018) causing more than 40% of serious industrial pollution incidents in the countries they operate (Murnaghan, 2009). Therefore, achieving sustainability transition needs to include SMEs given their crucial role in the economy, their environmental footprint (Koirala, 2019), and their capability to generate and employ clean technologies (OECD, 2017). To this end, the Green Employment Initiative (European Commission, COM/2014/446-a) and the Green Action Plan (European Commission, COM/2014/0440-b) provide the framework for SMEs to further benefit economies by creating green jobs (Moreno-Mondéjar et al., 2021).

In the case of SMEs, the literature has extensively explored the factors of initial adoption of RE actions such as reducing energy use, minimizing waste and re-using of raw materials (Garrido-Prada et al., 2021; Cunha et al., 2020; Özbugday et al., 2020). However, what has so far been ignored is an examination of factors that make SMEs stay committed in RE actions. Even though European directives “set the scene” for long-term commitment, there is scarcity of evidence to document not only initial adoption but also commitment to RE actions, especially given that the latter has been the focus only in recent European policy directives.

Thus, in this paper we explore *what are the factors affecting adoption and commitment of SMEs in resource efficiency actions to achieve sustainability transition*. We use data in waves, provided by the European Commission including 37,438 European Small-Medium Enterprises in the EU-28 for the 2013 to 2017, a relatively stable economic period for

the EU. We also incorporate country-specific and time-varying characteristics. Thus, by considering both the micro- as well as the macro-level, we argue that commitment to RE actions promoting sustainability transition is feasible through several RE “enhancers”. As enhancers we define and identify elements that support adoption and stated commitment to RE from our dataset, such as integration of new technology paradigms and cooperation networking, external support sources such as financial support and specialized consulting, as well as the attitude of the country towards sustainability such as the eco-innovation performance and renewable energy consumption. To the best of our knowledge, this is the first study to examine the enhancers of *commitment* in RE actions of SMEs, instead of exploring the factors for *initial adoption* by bringing together firm-level characteristics as well as macro-level attributes.

Specifically, as enhancers at the firm level we consider SMEs production technology and use of self-assessment tools (Schleich and Fleiter, 2019), their knowledge of the availability of funding and of funding sources (Demirel and Danisman, 2019), collaboration between SMEs and public and private organizations (Montalvo, 2008), as well as knowledge transfer (Colombo et al., 2021) and SMEs' adoption of regulatory frameworks (Montalvo, 2008). At the country-level, we consider as a potential enhancer the existence of regulatory frameworks (Moreno-Mondéjar and Cuerva, 2021) and the immediate economic environment a firm operates in (Giudici et al., 2019). However, it is common for technology to be considered a barrier to RE adoption by SMEs, as new technologies are not always up to par with SMEs demands (Lopez et al., 2019), especially since the prescriptive nature of most regulatory frameworks prevents radical innovation or changes in the production process (Montalvo, 2008). Nevertheless, (Bocken et al., 2016) highlight the need to investigate strategies and circular-practices-enabling technologies.

Barriers for firms can also occur at the planning phase of future actions, with the literature showing that prior engagement and knowledge of RE activities in SMEs determines whether regulations, financing and administrative burden are considered by SMEs as barriers (García-Quevedo et al., 2020). Firm size is also expected to influence adoption of RE actions by SMEs. Past studies have shown that smaller SMEs are less likely to engage in RE (Chatzistamoulou and Tyllianakis, 2022) and are less likely to adopt innovative approaches to production and energy use (Garrido-Prada et al., 2021; Bassi and Dias, 2019). We explain in detail the reasons for including these factors in our analysis in the following section.

This paper therefore contributes to the SMEs and RE literature interested in examining, supporting, and forecasting the mechanisms of sustainability transition. We consider (i) the factors of the decision to adopt a RE action, (ii) the RE enhancers influencing future commitment and (iii) the attitude of each member state towards sustainability transition. To do so, we employ a binary response probit model with sample selection allowing to examine whether SMEs commit in RE actions in the future, given they already implement such actions. In addition, through the selection equation we investigate the factors influencing the decision to adopt RE actions in the first place.

Findings indicate that during the period of study there has been a change in the structure of incentives of the firms, as in the beginning of the period (i.e., 2013) adoption of RE actions and future commitment were perceived as independent decisions. However, after a buffer period of three years from the launch of the Resource Efficiency Flagship Initiative (i.e., 2014–2015), a change in the incentives to stay committed in RE actions occurred. From that point onwards, the decisions to adopt and stay committed in RE actions appear interlinked. We document that commitment is reinforced by the integration of new technology paradigms, funding, cooperation possibilities and network development and well-defined regulation of using secondary raw materials. Specialized advice and business consulting on RE actions also foster commitment. Although barriers in implementing RE actions do exist, firms are not deterred by those and pursue sustainability transition. The macro

environment characteristics such as resource productivity and green energy positively and systematically affect commitment, whereas discrepancies in eco-innovation performance across the EU-28 inhibit to some extent sustainability transition. Competitiveness exerts a positive systematic influence on the decision to stay committed promoting sustainability transition. All in all, findings advocate commitment in RE actions to achieve sustainability transition is a feasible reality rather than an elusive goal.

The paper is structured as follows. Section 2 presents the related literature and research hypotheses, Section 3 describes the dataset along with the empirical strategy, Section 4 discusses the results and policy implications while Section 5 provides recommendations for future actions.

2. Existing knowledge and research questions

In this paper we examine the factors affecting SMEs commitment in RE actions, and thus promote sustainability transition. In other words, we contribute to the relevant literature by investigating *what are the RE enhancers that determine firms' commitment in RE business strategies*. To investigate this, we rely on the recent literature for factors that can affect RE actions and then, we group those factors in three blocks of research hypotheses.

Although the literature showcases an increasing interest regarding the betterment of production technology based on the technological paradigm applied to different business models (e.g., Bocken et al., 2016), the focus has mainly been on energy consumption (Cunha et al., 2020; Özbugday et al., 2020). In effect, integration of new technologies mainly refers to matters of energy generation and efficiency (e.g., Schipfer et al., 2022), and less often on the use of technologies such as information technology as means of improving RE (e.g., Tärstena et al., 2020). Promoting RE in early stages of production through integration of new technologies is expected to reduce resource use, as such technologies aim to enhance material recyclability and increase their absorption back to the production (Bocken et al., 2016). Indeed, new, cross-sectoral technologies can also be considered as enhancers for adopting RE, both at the sectoral- and firm-level (Rohn et al., 2014).

In line with the above, the firm's ability to determine the efficiency and appropriateness of already adopted actions is expected to influence RE adoption. In this paper this ability is defined as using self-assessment tools at the firm-level to examine RE actions' uptake. So far, the literature has focused on external measures of RE such as energy audits (Schleich and Fleiter, 2019). However, the consensus is that overcoming information barriers could result in RE adoption (Kalantzis and Revoltella, 2019) and be evidence of a firm being already in a sustainable path (Chatzistamoulou and Tyllianakis, 2022). A firm's ability to evaluate actions taken to boost RE also directly relates to the existence of know-how, such as aspects of implementation and cost-efficiency of actions (Schleich and Fleiter, 2019). For example, Cunha et al. (2020) studying Portuguese SMEs, find the lack of know-how as the main barrier to adopting energy efficient practices, remaining on existing energy usage systems instead. Thus, the first block corresponding to the enhancers of RE actions implementation contains the adoption and implementation of performance-enhancing technology (*Hypothesis 1a*), funding (*Hypothesis 1b*), collaboration (*Hypothesis 1c*), and well-structured regulatory framework (*Hypothesis 1d*). In the form of a testable hypothesis, *Hypothesis 1a* is stated as follows:

H1a. The integration of new technology paradigms has a positive effect on firm willingness to stay committed in RE actions.

Availability of funding and knowledge about funding sources has been widely demonstrated to influence adoption of RE actions. Specifically, external funding provided by banks, governments or the EU has been found to negatively influence adoption of RE actions in SMEs (Garrido-Prada et al., 2021; Demirel and Danisman, 2019). Different types of funding also result in a differentiated effect on RE adoption, as

venture capital and equity finance have been shown to be more likely to support SMEs' adoption of circular economy practices (Garrido-Prada et al., 2021; Demirel and Danisman, 2019). The effect of self-funding appears to be inconclusive, as the literature provides examples of both a decrease (e.g., Ghisetti and Montessor, 2020) as well as an increase in the likelihood to adopt RE strategies (e.g., Chatzistamoulou and Tyllianakis, 2022). Such being the case, *Hypothesis 1b* is formed as:

H1b. Funding sources' adequacy is positively associated with firm willingness to stay committed in RE actions.

Collaboration, usually taking place in projects involving academic and research institutions, can also boost adoption of RE actions (Anciaux et al., 2016). Collaboration is a priority of the new SME Strategy for a sustainable Europe (European Commission, COM/2020/103-a) and an integral part of the EU's new Circular Economy Action Plan (European Commission, COM/2020/98-b). It also promotes circular economy actions amongst SMEs across industries. Consumer preferences can also influence eventual adoption of RE actions, especially if they indicate that they are willing to pay higher premium for such products (Montalvo, 2008). Such an effect can encourage firms to collaborate during the production process as collaboration involves expertise and knowledge transfer among the parties involved. However, literature provides mixed results on the effect of knowledge transfer with positive (e.g., Colombo et al., 2021), negative (e.g., Statsenko et al., 2020) or no effect (Moaniba et al., 2019) on eco-efficiency being reported. Overall, literature on the effect of collaboration on RE strategies promoting green growth is scarce (Anciaux et al., 2016). This paper aims to fill such a gap and thus, *Hypothesis 1c* is stated as:

H1c. Collaboration and networking development exert a positive influence on firm willingness to stay committed in RE actions.

Adoption of regulatory frameworks such as ISO certification is considered to increase RE adoption (Montalvo, 2008). Singh et al. (2015) show that ISO 14001 certification is attributed for a 25% decrease in SMEs' waste in India, while other ISO certifications exist to promote reduced material use in SMES such as ISO14040 and ISO14044 (Campitelli et al., 2019). More generally, clearly defined regulatory frameworks are expected to support continuous commitment of SMEs to RE actions as they reduce uncertainty, make SMEs less dependent of primary material and enhance use of new technologies (European Commission, 2020-c). Therefore, *Hypothesis 1d* for the effect of the regulatory framework is as follows:

H1d. A well-defined regulation framework exerts a positive influence on firm willingness to stay committed in RE actions.

The industry structure firms operate in is also expected to impact their level of commitment to undertake RE actions (Kedir and Hall, 2021) as well as a firm's environmental predisposition (Sendawula et al., 2020). In effect, Bodas-Freitas and Corrocher (2019) indicate that initial adoption of RE actions should involve re-engineering and re-adaptation of processes if firms wish to continue being in a RE path. Nevertheless, as Bodas-Freitas and Corrocher (2019) note, "*expert advice and access to funding become more important after the initial adoption of RE actions*". This forms the second block of factors describing external support to enhance commitment, is expressed by the following testable hypothesis:

H2. External support has a positive influence on the decision to adopt and stay committed in RE actions.

Country-wide effects, such as regulatory frameworks, can also drive adoption of RE, even in the absence of economic returns for SMEs (Gadenne et al., 2009) but regulations' impact depend on the level of RE investment and capabilities of SMEs (Moreno-Mondéjar et al., 2020). In the EU, first the introduction of Waste Management Directive (European Commission, 2008/98) and then that of the Ecodesign Directive (European Commission, 2009/125-a) intend to strengthen waste recovery and reuse. In particular, the Ecodesign Directive (European Commission, 2009/125-a) aims at supporting the continuous improvement of

products through responsible energy use, but this tends to overlook other RE and environmental aspects (Bundgaard et al., 2017). Overall, in the EU, current regulations are seen rather as impeding RE adoption, since they increase costs and prices of products, have inconsistent requirements (Rizos and Bryhn, 2022), and are a source of investment risk for SMEs (Daou et al., 2020). This is evident given the limited resource recovery and reuse of European SMEs (only 25% of waste materials of SMEs are resold, compared to 45% for larger companies (European Commission Factsheets, 2019).

The immediate economic environment a firm operates in is also expected to enhance adoption of RE. For example, SMEs in countries of high environmental awareness might be incentivized to adopt and stay committed to RE actions (Bodas-Freitas and Corrocher, 2019; Giudici et al., 2019). Similarly, a country's absorptive capacity (the amount and diffusion of scientific and know-how information) also influences RE adoption (Garrido-Prada et al., 2021; Gkypali et al., 2019). For example, Robaina et al. (2020) find that countries with high levels of RE are also showing high levels of resource productivity (a way of measuring a country's performance in transitioning towards a circular economy). This forms the final testable hypothesis (*Hypothesis 3*) as:

H3. The country's attitude towards sustainability influences the decision of the firm to adopt and stay committed in RE actions.

To the best of our knowledge, this is the first study to examine the enhancers of *commitment* in RE actions of SMEs, instead of exploring the factors for *initial adoption* of RE actions by bringing together firm-level characteristics as well as macro-level attributes to study whether commitment of SMEs to RE actions fosters sustainability transition.

3. Data & econometric strategy

3.1. Data

The paper employs data on 37,438 European Small-Medium Enterprises (onwards SMEs) on resource efficiency drawn from the *Flash Eurobarometer 381* (11,207 SMEs), 426 (13,114), and 456 (13,117), titled "Small and Medium Enterprises, Resource Efficiency and Green Markets" covering the EU-28 member states¹ over a three-year period (European Commission, 2014c, 2016, 2018-e). The waves correspond to 2013, 2015, and 2017 respectively, including information on the micro-environment of the firm. The unit of analysis is SMEs across the EU-28 for the years considered and has been acknowledged by earlier studies to provide useful insights (Majid et al., 2020). The final dataset is a series of cross-sectional surveys. For each wave a completely new and independent sample is drawn that best represents the entire population being studied. The dataset provides the opportunity to study the decision-making process of a large sample of SMEs across the EU-28 over a time window sufficiently wide to explore behavior change over the period covered.

The micro-level characteristics influencing resource efficiency activities² are categorized further into the (i) resource efficiency enhancers such as integration of new technology paradigms and cooperation possibilities or network development, (ii) external support sources such as funding type and access to professional consulting, (iii) firm-specific

¹ Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Rep., Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden, United Kingdom. The latter has been included as during period covered by the dataset, the UK was subject to the European policy directives and was reporting data on the respective indicators.

² Activities promoting resource efficiency include whether a firm undertakes actions related to (i) saving water, (ii) saving energy, (iii) using mainly renewable energy, (iv) saving materials, (v) minimizing waste, (vi) trading scrap, (vii) recycling-reusing materials, and (viii) designing sustainable products.

heterogeneity such as firm size and turnover change, and (iv) resource efficiency barriers such as complexity of procedures and lack of environmental expertise. Moreover, we augment the dataset by including macro-level characteristics such as country- and time- varying variables capturing the attitude of the country towards sustainability affecting the decision of the firm to adopt a RE action (Chatzistamoulou and Tyllianakis, 2022), through various specialized databases.

The macro-level attributes capture the attitude of the country towards sustainability transition as well as reflect the institutional framework of the country economy SMEs operate under. Specifically, the former block of variables includes the following aspects. The profile of the country towards sustainability is captured by resource productivity and eco-innovation index, indicators of the Resource Efficiency Scoreboard part of the Roadmap to a Resource Efficient Europe, the circular material use capturing aspects of the Sustainable Development Goal 12 'Responsible Consumption & Production', collected via Eurostat (2022).

Data on the eco-innovation index has been collected via the Eco-innovation Scoreboard of the DG Environment Eco-Innovation Action Plan, published by the Eco-Innovation Observatory and Eurostat. The eco-innovation index, encapsulating several five thematic areas³ and many specific indicators, captures a country's eco-innovation performance and thus represents a country' attribute towards sustainability as well as green transition (Chatzistamoulou and Tyllianakis, 2022; Binswanger, 2001). Moreover, literature recognizes this index as an adequate measure of reflecting the eco-innovation level as it relies on theory-driven indicators (Park et al., 2017).

Data on the renewable energy use capturing aspects of the Sustainable Development Goals 7 'Affordable & Clean Energy' and 13 'Climate Action' is collected through the World Bank database, for the respective years in each wave of the Eurobarometer surveys (World Bank, 2022). The final block of information capturing the functionality of the production environment is captured by hand-collected data on the Global Competitiveness Index (GCI), capturing the competitiveness level of each country. Data is collected through the Global Competitiveness Report produced by the World Economic Forum on an annual basis (Sala-i-Martin et al., 2008; Sala-i-Martin and Artadi, 2004). This multi-faceted index includes twelve pillars,⁴ common across countries facilitating benchmarking and used previously in explaining cross country productivity differential, knowledge, and absorptive capacity differentials (Tsekouras et al., 2017). Moreover, data on regulation is collected and produced by the Fraser Institute (Fraser Institute, 2022) as regulation is considered an integral part of measuring the functionality of each economy (Chatzistamoulou and Koundouri, 2022), and thus the production environment of the firm.

Table 1 below provides the descriptive statistics, sources and a brief description of the variables used. The micro-environment characteristics indicate that although RE adoption demonstrates variations, SMEs' willingness to commit to actions promoting RE increases over the years. RE enhancers appear moderately high as is the turnover. RE barriers do not seem to inhibit consideration of adopting a green business strategy. Macro-economic factors remained relatively stable across the study period, with Eco-innovation performance across the EU-28 incrementally improving.

3.2. Econometric strategy

This paper investigates *what are the factors affecting adoption and*

³ Eco-innovation Inputs, Activities and Outputs, Socio-economic Outcomes, Resource efficiency Outcomes.

⁴ Pillars include Institutions, Infrastructure, Macroeconomic Environment, Health and Primary Education, Higher Education and Training, Goods market efficiency, Financial market development, technological readiness, market size, business sophistication and innovation.

Table 1
Variables, sources, and descriptive statistics.

Variables	Brief description & units of measurement	Source	Frequency		
			Year		
			2013	2015	2017
Micro-environment characteristics					
RE active	Engaged in actions promoting RE	European Commission	90.16%	84.79%	88.21%
RE actions commitment	Willingness to commit in actions promoting RE in the future	EU Open Data Portal	4.03%	23.91%	75.55%
RE enhancers	Integration of new technology paradigms		44.43%	42.26%	35.90%
	Funding related		50.77%	46.29%	47.69%
	Cooperation possibilities-network development		18.83%	19.28%	22.88%
	Well-defined regulation on using secondary raw materials		–	15.48%	15%
Firm-specific heterogeneity	Increased turnover over the last past two years		33.47%	40.31%	48.33%
	1-9 Full-time eq. employees (category 1)		45.50%	.3%	.78%
	10-49 Full-time eq. employees (category 2)		34.51%	.45%	.9%
	50-249 Full-time eq. employees (category 3)		20%	.27%	.68%
External support sources	Public funding		5.05%	5.37%	7.33%
	Private funding		4.3%	5.22%	6.98%
	Comradeship funding		.94%	1.30%	1.38%
	Non-financial public administration advice		4.43%	4.58%	5.98%
	Non-financial private consulting		8.59%	9.14%	11.48%
	Business associations' consulting		6.4%	6.71%	8.55%
RE barriers	Complexity of procedures		25.64%	24.04%	29.02%
	Environmental legislation adaptivity issues		15.55%	15.73%	17.38%
	Legislative technicalities issues		11.92%	12.64%	15.97%
	Cost of environmental actions		22.54%	20.25%	22.49%
	Lack of environmental expertise		17.60%	15.57%	15.77%
	No required products or services supply		–	9.29%	11.24%
	Lack of demand for RE actions		–	14.97%	14%
Observations	Number of SMEs		11,207	13,114	13,117
Country attitude towards sustainability transition			Mean (Standard Deviation)		
Resource productivity	Gross domestic product to domestic material consumption (euro/kg).	Eurostat – Europe 2020	1.81 (1.11)	1.81 (1.12)	1.88 (1.20)
Renewable energy use	Share of total final energy consumption (percentage)	World Bank Database	19.6 (11.4)	21.26 (11.87)	21.4 (11.66)
Circularity rate	Ratio of circular use of materials to the overall material use. It measures the material recovered and fed back into the economy (% of total material use).	Eurostat – Circular Economy	9.02 (6.06)	8.69 (6.05)	9.24 (6.61)
Eco Innovation index	Eco-innovation performance across the EU-28 (number)	Eco-Innovation Observatory & Eurostat, DG Environment	84.29 (35.63)	87.8 (28.04)	92.98 (27.74)
Global competitiveness index	Global Competitiveness Index score (number)	World Economic Forum	4.71 (.5)	4.76 (.49)	4.84 (.49)
Regulation	Reflects regulatory restraints affecting economic freedom (number)	Economic Freedom-Fraser Institute	7.71 (.44)	7.83 (.48)	7.9 (.43)

commitment of SMEs in RE actions to achieve sustainability transition. However, commitment in RE actions is not random since it is based on the current behavior of the firm i.e., SMEs select to adopt a RE strategy. The latter causes and upward bias to the chance of commitment (Heckman, 1979; 1976; Gronau, 1974). Therefore, firms already implementing RE actions self-select to stay committed. Thus, it is theoretically possible that unobservable or mismeasured factors may affect both the decision to stay committed and the decision to adopt a RE action. Thus, a selection mechanism is needed to explore whether the two decisions are independent. This requires the use of an empirical strategy accommodating for the two decisions, while accounting for selectivity bias. The appropriate method is to employ the binary response probit model with sample selection (Van de Ven and Van Praag, 1981), to provide consistent and asymptotically efficient estimates for all the parameters of interest.

Specifically, the dependent variable of the outcome equation (RECommitment) reflects whether a firm intends to stay committed in RE actions within the next two years, since such activities point towards achieving the same goal (Katz-Gerro and López Sintas, 2019). The dependent variable of the selection equation corresponds to whether an SME has adopted a RE action (RE). The model can be described as follows using the selection equation and the outcome equation:

$$RE_{ijt} = \alpha_0 + \beta FirmHeterogeneity_{ijt} + \gamma ExternalSupport_{ijt} + \delta REbarriers_{ijt} + \lambda MacroEnvironment_{ijt} + u_{ijt} \tag{1}$$

$$RECommitment_{ijt} = \mu_0 + \mu REenhancers_{ijt} + \zeta FirmHeterogeneity_{ijt} + \theta ExternalSupport_{ijt} + \tau MacroEnvironment_{ijt} + \varepsilon_{ijt} \tag{2}$$

The specification of the selection equation allows for the investigation of the factors of the decision to adopt a RE action while the outcome equation investigates the factors shaping the decision of the firm to stay committed in such actions. RE enhancers are used only in the outcome equation as those are used to identify what influences commitment in RE actions, after the initial set up of RE actions, whereas RE barriers are encountered when trying to set up RE actions i.e., at the initial decision. After the initial set up the firm gains experience, and thus can internalize any changes across the years. Thus, RE barriers intend to identify the initial decision to adopt RE actions. Moreover, the selection equation should contain at least one variable that is not in the outcome equation to be identified.

The parameters to be estimated are the $\alpha_0, \mu_0, \beta, \gamma, \delta, \lambda, \mu, \zeta, \theta, \tau$ while ε_t and u_t are the disturbance terms of the selection and outcome equation respectively.

4. Results and discussion: what keeps SMEs committed to resource efficiency actions?

Table 2 below presents the estimation results (coefficients and standard errors), Table 3 presents the percentage of SMEs committed in RE actions, while Table 4 presents the average marginal effects for the factors affecting the decision of the SMEs to commit in RE actions in the future. It is noticeable that the percentage of SMEs in 2013 that implement a RE action and plan to commit in such actions is quite low (see Table 3). Thus, we would expect that those decisions will not be considered as independent for the SMEs in 2013. Indeed, the Wald test of independence of the two decisions, in the lower part of Table 2, does not appear to be significantly different from zero, indicating no selection effect (i.e., the two decisions are perceived as independent in that year).

However, in 2015 and 2017 there is strong evidence to support that the null of $\rho = 0$ i.e., independence between the two decisions is not accepted, indicating the existence of a selection effect. This documents a shift in the structure of incentives of the SMEs towards commitment to RE actions. In other words, as time goes by, SMEs appear to realize the benefits of committing to a business strategy fostering RE, as part of their green business agenda. Such an effect could be supported by the subsequent introduction of policy initiatives in the EU starting in 2014 when the Green Action Plan (European Commission, COM/2014/0440-b) was launched to foster the green growth of SMEs (Moreno-Mondéjar et al., 2021; Sulich and Rutkowska, 2020).

However, it was not until 2015, and later in 2018 and 2020, where the European Union through its policy framework such as the Circular Economy Action Plans (European Commission, COM/2015/614-a; COM/2018/028-e; COM/2020/98-b respectively), the InvestEU programme (European Commission, COM/2018/439-c) and the European Green Deal (European Commission, COM/2019/640) European Commission, COM/2019/640), incentivized sustainability transition. This translates in a change in the structure of incentives of the SMEs in the dataset for the period examined, to extend their business agenda through circular economy actions and RE. In what follows, we focus on the post-2013 period.

Regarding the micro-environment of the firm, and particularly the block of RE enhancers (first block), it is noticeable that all are quite influential (Tables 2 and 4). Particularly, the integration of new technology paradigms such as new self-assessment tools to evaluate RE performance or the demonstration of new technologies extent the internal knowledge base of the firm (Rohn et al., 2014) building the capacity to facilitate future commitment (H_{1a} is not rejected). This finding is in line with the recent report of the European Commission about recommendations for action to improve European SMEs' access to advanced technologies, since those are the flagship of Europe's growth potential for providing technological knowledge and support in accessing solutions to improve business operation (European Commission, 2021-b; Van de Velde and Núñez, 2021).

Funding such as grants and subsidies or information on funding possibilities exerts a positive and systematic influence on the chance to remain committed in RE activities (H_{1b} is not rejected). This finding echoes the results of Chatzistamoulou and Tyllianakis (2022) who find evidence that European SMEs with access to information on funding tools related to green activities are by 65% more likely to adopt a circular economy promoting activity. It is also acknowledged by the literature that procurement of funding augments the business agenda and enhances operations (Greco et al., 2017; Segarra-Blasco and Arauzo-Carod, 2008).

Findings support that collaboration and networking development positively affect firm commitment to RE actions (H_{1c} is not rejected). There is an ongoing discussion about the role of collaboration, especially in the context of R&D collaborations, and therefore evidence on its impact is quite mixed. From the one hand, collaboration may exert a positive effect for the participating firms (Colombo et al., 2021; Findik and Beyhan, 2015; Tödting et al., 2009), a negative one associated with

communication and transaction micro-management barriers among the partners (Statsenko et al., 2020; Gkypali et al., 2017, 2018; Kafourous et al., 2015) or have no systematic effect (Moaniba et al., 2019). However, literature on the effect of collaboration on RE actions promoting sustainability transition is scarce (Anciaux et al., 2016) and, to our knowledge, this is the first paper that documents a positive relationship with respect to RE.

Regarding the impact of the regulation framework on RE actions commitment, we find evidence that SMEs appreciate well-organized frameworks which assist in minimizing the environmental footprint of their operations and, in turn, have a positive effect on RE commitment (H_{1d} is not rejected). Such findings are in line with studies documenting the positive impact of environmental management systems on the environmental product innovation (Papagiannakis et al., 2019) and waste reduction (Singh et al., 2015). Melnyk et al. (2003) also provide evidence that firms adopting and implementing a formal environmental management system to reduce waste, exert a positive impact on environmental performance in contrast to the firms with an uncertified system. Well-defined regulatory frameworks can also increase the demand for green products (Kammerer, 2009). However, evidence also suggests that firms engaging in green activities might experience reduced performance (Tumelero et al., 2019; Lee and Min, 2015).

Shifting the attention to the external support channels (second block, Tables 2 and 4) as a block of factors affecting commitment to RE actions, it is noticeable in our results that the bundle of possible support options, either in the form of funding or specialized guidance, is important (H_2 is not rejected). More precisely, public funding exerts a positive and systematic influence on the willingness to commit in RE actions. This is in line with a growing body of literature highlighting the role of public funding, either at a national or European level on firm performance measures such as innovation efficiency (Spanos, 2021; Caravella and Crespi, 2020; Leckel et al., 2020; Costantini et al., 2015). When designing their business agenda, SMEs do seem particularly keen to rely on private funding schemes, most likely as alternative means of finance usually are available to only a small number of SMEs (Demirel and Danisman, 2019). However, other studies find evidence that self-funding is the most influential source of boosting the adoption of green activities, especially regarding the circular economy-promoting activities (Chatzistamoulou and Tyllianakis, 2022).

Considering the effect of the country profile (block three, Tables 2 and 4), this exerts a significant effect on commitment to RE actions ($Hypothesis 3$ is not rejected). Resource productivity has a positive and systematic influence on SMEs commitment to RE actions. This is an indication that the attitude of the country towards the promotion of sustainability principles modulates the components of environmentally conscious production (Chatzistamoulou and Tyllianakis, 2022). Findings in the literature are quite contradictory, as evidence regarding the effect of the country environment is found to be either positive (Ilić and Nikolić, 2016) or negative (Robaina et al., 2020). We find a weak, yet positive and systematic effect of renewable energy use, in line with the some of the existing evidence (Mavi and Mavi, 2019; Mikulčić et al., 2019).

Although the literature casts doubt on the appropriateness of circularity indices because of the misguided accountable aspect of the environment (Haupt and Hellweg, 2019), we provide evidence that the circularity rate would promote engagement with RE. Eco-innovation exerts a weak influence on commitment in RE actions, as there are sustainability and technological differences between the member states (Chatzistamoulou and Koundouri, 2021), as well as differences in institutional framework deepening technological inequality (Bianchi et al., 2020; Caravella and Crespi, 2020). However, it is common for technology to be considered a barrier to RE adoption by SMEs, as new technologies are not always up to par with SMEs demands (Lopez et al., 2019), especially since the prescriptive nature of most regulatory frameworks prevents radical innovation or changes in the production process (Montalvo, 2008). In addition, it is acknowledged by the recent

Table 2
 Estimation results of the sample selection model: Coefficients & Robust Standard Errors.

Outcome equation (Eq (2)): Selection Equation (Eq (1)):	SMEs willingness to commit in RE actions					
	SMEs adopting RE actions					
	2013		2015		2017	
	OE	SE	OE	SE	OE	SE
Blocks of variables affecting RE actions						
Micro-environment						
<i>RE enhancers (Hypotheses 1a-d)</i>						
Integration of new technology paradigms (H_{1a})	-.019 (.047)	-	.164*** (.026)	-	.159*** (.030)	-
Funding related (H_{1b})	.158*** (.048)	-	.092*** (.026)	-	.186*** (.028)	-
Cooperation possibilities-network development (H_{1c})	-.011 (.058)	-	.178*** (.030)	-	.167*** (.034)	-
Well-defined regulation on using secondary raw materials (H_{1d})	-	-	.166*** (.033)	-	.267*** (.041)	-
External support sources (Hypothesis 2)						
Public funding	.052 (.106)	.139 (.138)	.179*** (.057)	.484*** (.161)	.155** (.070)	6.475*** (.070)
Private funding	-.094 (.119)	.477*** (.162)	-.001 (.056)	.639*** (.162)	.090 (.064)	6.645*** (.071)
Comradeship funding	-.436 (.289)	.680 (.432)	.279*** (.100)	.299 (.263)	-.041 (.130)	6.268*** (.081)
Non-financial public administration advice	.086 (.116)	.291 (.181)	.086 (.062)	.370** (.174)	.227*** (.080)	6.520*** (.135)
Non-financial private consulting	.057 (.086)	.246** (.114)	.000+ (.046)	.650*** (.127)	.054 (.055)	6.261*** (.052)
Business associations' consulting	.006 (.101)	.523*** (.155)	-.031 (.053)	.641*** (.154)	.197*** (.066)	6.273*** (.067)
Macro-environment						
<i>Attitude towards sustainability (Hypothesis 3)</i>						
Resource productivity	-.037 (.043)	.118*** (.033)	.110*** (.022)	.184*** (.029)	.118*** (.026)	.298*** (.036)
Clean technologies: renewable energy consumption	.004*** (.001)	-.003 (.002)	.004*** (.001)	.002 (.002)	.006*** (.002)	-.005* (.002)
Circularity rate	.008*** (.007)	-.024*** (.005)	-.014*** (.001)	-.024*** (.004)	.006* (.004)	-.024*** (.005)
Eco Innovation index	.008*** (.002)	.002 (.001)	-.004*** (.001)	-.002* (.001)	-.012*** (.001)	.003** (.001)
GCI	-.425*** (.116)	.148 (.090)	.278*** (.061)	.323*** (.069)	.107* (.057)	.172** (.080)
Regulation	-.122** (.063)	-.081* (.049)	-.252*** (.036)	-.084** (.041)	.077* (.045)	-.101* (.059)
RE barriers						
Complexity of procedures	-	.522*** (.057)	-	.783*** (.070)	-	6.781*** (.064)
Environmental legislation adaptivity issues	-	.126** (.069)	-	.633*** (.102)	-	6.555*** (.049)
Legislative technicalities issues	-	.317*** (.092)	-	.565*** (.11)	-	6.598*** (.055)
Difficulty in choosing appropriate resource efficiency action	-	.373*** (.079)	-	.572*** (.093)	-	6.682*** (.042)
Cost of environmental actions	-	.419*** (.063)	-	.653*** (.080)	-	6.620*** (.062)
Lack of environmental expertise	-	.480*** (.073)	-	.484*** (.094)	-	6.502*** (.077)
No required products or services supply	-	-	-	.599*** (.130)	-	6.726*** (.092)
Lack of demand for resource efficiency actions	-	-	-	.675*** (.087)	-	6.755*** (.053)
Firm-specific heterogeneity						
Increased turnover	-	.057 (.039)	-	.064** (.032)	-	.145*** (.038)
Size category 1 (small firms)	-.164 (.251)	-.435*** (.058)	-.164 (.251)	.175 (.256)	-.233 (.170)	-.456** (.183)
Size category 2 (relatively small firms)	-.026 (.182)	-.259*** (.060)	-.026 (.182)	.376* (.229)	.201 (.174)	-.240 (.176)
Size category 3 (large firms)	-	-	-.182 (.238)	.129 (.295)	.635** (.269)	.511** (.240)

(continued on next page)

Table 2 (continued)

Outcome equation (Eq (2)): Selection Equation (Eq (1)):	SMEs willingness to commit in RE actions					
	SMEs adopting RE actions					
	2013		2015		2017	
	OE	SE	OE	SE	OE	SE
Blocks of variables affecting RE actions						
Micro-environment						
RE enhancers (Hypotheses 1a-d)						
Sector effects (NACE II)	Yes	Yes	Yes	Yes	Yes	Yes
Model information						
Obs Selected	10,104		11,119		11,571	
Obs Non-Selected	1103		1995		1546	
Model p-value	.000		.000		.000	
p-value of Wald test of indep. eqns. (rho = 0)	.814		.000		.000	
Corr(Errors of SMEs willing to commit in RE actions, errors of SMEs implementing RE actions)	.058 (.249)		-.516*** (.049)		-.693*** (.108)	

Notes: (i) all models include constants, (ii) coefficients and robust standard errors in parentheses, (iii) stars indicate statistical significance at 1% “***”, 5% “**”, 10% “*”, “.”

Table 3

Crosstabulation of the main decisions of the SMEs.

SMEs adopting RE actions	SMEs commitment to RE actions	
	2013	Yes
No	97.46%	2.54%
Yes	95.80%	4.20%
	2015	
No	95.24%	4.76%
Yes	72.65%	27.35%
	2017	
No	80.92%	19.08%
Yes	16.90%	83.10%

literature that there are heterogeneous mechanisms accompanying the operations of SMEs since those face different challenges (Van de Velde and Núñez, 2021).

Competitiveness mostly positively influences commitment in RE actions since a well-operating production environment with robust institutions and mechanisms guarantees security in firm operations enabling them to internalize progress and technological developments, in line with the literature (e.g., Arranz et al., 2019; Chatzistamoulou et al., 2019; Gkypali et al., 2018; Triguero et al., 2013). Regarding regulation, it appears that the stringency of regulation at the country level would be beneficial for commitment to RE actions, proving evidence against the Porter Hypothesis (Fabrizi et al., 2018; Porter and Van der Linde, 1995). This finding is in line with the institutions-based standpoint indicating that firms’ decision-making process is affected by the regulatory framework at the national level (Elango and Dhandapani, 2020), as institutions matter in national resource allocation (Amankwah-Amoah et al., 2021).

We also account for several firm-specific characteristics (Belderbos et al., 2018; Wadho and Chaudhry, 2018), both for the outcome and selection equation, to find that heterogeneity matters (Dosi et al., 2010). Our findings document that firm size matters in line with the literature, as studies have shown that smaller SMEs are less likely to engage in green strategies (Chatzistamoulou and Tyllianakis, 2022) and less likely to adopt innovative approaches to production and energy use (Garrido-Prada et al., 2021; Bassi and Dias, 2019). Increased turnover appears to be impacting the decision to implement RE actions (Özbuğday et al., 2020). Results are also in line with empirical evidence regarding the

eco-innovation behavior of firms with small to large sizes, compared to very large firms (Garrido-Prada et al., 2021; Bassi and Dias, 2019). Barriers for firms can also occur at the planning phase of future actions, with the literature showing that prior engagement and knowledge of RE activities in SMEs influence whether regulations, financing and administrative burden are considered by SMEs themselves as barriers (Garcia-Quevedo et al., 2020).

Besides firm heterogeneity and country-specific effects that have been discussed, considering the positive and systematic effect of external support sources, evidence points towards SMEs’ decision to adopt a RE action for the first time requiring all the support they can have access to. Such support can come from funding availability and its quality (Özbuğday et al., 2020), support, expert information, and advice (Bodas-Freitas and Corrocher, 2019) and environmental knowledge spillover effects (Aldieri et al., 2022). Evidence provided herein indicates that the bundle of RE barriers, does not discourage SMEs to adopt and implement a RE action. Such a finding has been previously reported in the literature, for example Stoever and Weche (2018) find that changes in environmental regulation through the means of a water tax did not affect investments to achieve resource efficiency or overall firm competitiveness. Cainelli et al. (2020) find that existing environmental regulations enhance firms’ adoption of RE actions, arguing convincingly that regulatory frameworks can act as enhancers and not as barriers to adoption of RE.

All in all, factors of adoption of RE actions used in this study reflect the breadth of information currently identified by systematic literature reviews (e.g., Suchek et al., 2021) and of similar studies (e.g., Garrido-Prada et al., 2021; Cunha et al., 2020). In addition, other micro and macro environment factors such as marketing purposes from market-oriented organizations (Kalverkamp and Raabe, 2018) could also influence such a green agenda, but were not investigated here as those cannot be traced through official sources, not to mention that are beyond the scope of this paper.

5. Concluding remarks and future recommendations

The European Union during the last two decades has launched various directives to foster commitment in actions promoting Resource Efficiency (RE) to facilitate sustainable growth. Small-Medium Enterprises (SMEs) have long been considered as catalysts in achieving this combination of sustainable growth along with reaching net-zero goals. Although the literature has been quite elaborative on the factors affecting SMEs engagement in RE actions, no evidence exists on what affects commitment in such actions.

Table 4
Estimation results: Average Marginal Effects.

Factors affecting SMEs commitment in RE actions, provided that already implement such actions	2015	2017
Micro-environment		
<i>RE enhancers (Hypotheses 1a-d)</i>		
Integration of new technology paradigms (H_{1a})	.059*** (.009)	.034*** (.006)
Funding related (H_{1b})	.033*** (.009)	.040*** (.006)
Cooperation possibilities-network development (H_{1c})	.063*** (.011)	.036*** (.007)
Well-defined regulation on using secondary raw materials (H_{1d})	.060*** (.012)	.057*** (.009)
<i>External support sources (Hypothesis 2)</i>		
Public funding	.064** (.020)	.033** (.015)
Private funding	-.001 (.020)	.019 (.034)
Comradeship funding	.100*** (.036)	-.009 (.028)
Non-financial public administration advice	.031 (.022)	.049*** (.017)
Non-financial private consulting	.000+ (.016)	.012 (.012)
Business associations' consulting	-.011 (.019)	.042*** (.014)
Macro-environment		
<i>Attitude towards sustainability (Hypothesis 3)</i>		
Resource productivity	.039*** (.008)	.026*** (.006)
Clean technologies: renewable energy consumption	.001*** (.001)	.001*** (.000+)
Circularity rate	-.005*** (.001)	.001* (.001)
Eco Innovation index	-.001*** (.000+)	-.002*** (.001)
GCI	.100*** (.022)	.023* (.012)
Regulation	-.090*** (.013)	.017* (.010)
Firm-specific heterogeneity		
Size category 1 (small firms)	-.059 (.090)	-.050 (.037)
Size category 2 (relatively small firms)	-.009 (.065)	.043 (.037)
Size category 3 (large firms)	-.065 (.085)	.137** (.058)
Sector effects (NACE II)	Yes	Yes
Obs	3041	9, 615

Notes: (i) all models include constants, (ii) average marginal effects and robust standard errors in parentheses, (iii) stars indicate statistical significance at 1% “***”, 5% “**”, 10% “*”, (iv) the symbol “+” stands for a very small number.

Thus, we study *what are the factors affecting adoption and commitment of SMEs in RE actions to achieve sustainability transition*. We employ a dataset provided by the European Commission including 37,438 European SMEs in the EU-28 for the period 2013 to 2017 in waves, complemented by country-specific and time-varying attributes. The dataset covers the launch and implementation period of the Resource Efficiency Flagship Initiative within the Europe 2020 strategy for sustainable growth, allowing us to explore the change in the structure of incentives of the SMEs regarding the adaptation to new policy initiatives, incorporate lessons-learned and examine the factors such as funding and collaboration, affecting commitment towards RE actions.

Results show that SMEs appear to be already aware of the multitude of benefits in employing RE actions, so information campaigns should focus on supporting SMEs in the sustainable path they have chosen

instead of directing efforts in promoting adoption of RE actions. Specialized advice and business consulting emerge as key activities for SMEs that reinforce commitment to RE actions. Policy-wise, our study provides quantitative evidence that the main sources of influence for adopting RE actions are other than purely economic ones. They relate to cooperation, funding availability, advice, and macro-environmental indicators. This paints a more nuanced picture when considering long-term policy planning. It appears to support local and regional governments assuming the role of a facilitator instead of a regulator that allows ‘trail-blazing’ firms in adopting RE actions to operate. Policymakers’ role should then focus on creating a business ecosystem where on the one hand they remove obstacles to sustainability, burdensome regulations, and red-tape and on the other hand increase information provisioning. This is not a ‘laissez-faire’ suggestion but one that narrows down on the role of the EU and member states.

This study could be extended to include more waves and SMEs either in the form of survey or a longitudinal format to trace the structure of incentives and heterogeneity shaping commitment as time goes by, since more data become readily available by the European Union. In addition, other micro and macro environment factors such as marketing purposes from market-oriented organizations could also influence such a regime change. Evidence suggests that SMEs responded to the policy directive shifting their production paradigm and committed in RE, realizing that adopting and committing in RE actions goes together. Even though in the short-run SMEs needed an adjustment period, SMEs were found to be flexible in shifting the production paradigm onwards. Findings support that making SMEs integral part of the sustainability transition has the characteristics of a successful EU strategy, as it incentivized commitment in actions promoting RE.

Credit author statement

Nikos Chatzistamoulou: Conceptualization, Data curation, Methodology, Formal analysis, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization; Funding acquisition, Supervision. **Emmanouil Tyllianakis:** Resources and Review of Literature, Writing-Original draft preparation, Writing- Reviewing and Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available upon request.

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