Determinants of energy efficiency and renewable energy in European SMEs

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Abstract

This paper empirically investigates the factors driving the adoption of energy efficiency (EE) and renewable energy (RE) measures in a sample of 8,213 Small and Medium-Sized Enterprises (SMEs) in European countries. Our results suggest that sustainable energies actions (EE and RE) are highly persistent both at the firm level and across countries and that there are relevant complementarities between EE and RE practices, as well as other resource efficient practices. In addition, strategies for EE seem to rely more on cost saving and regulations, while those for RE are more linked to public support and environmental awareness. The paper ends with some recommendations for policymakers suggesting that Europe needs to design an energy policy for the SMEs firms that jointly pursues both EE and the diffusion of RE according to the technological gap of each member country.

Keywords: energy efficiency, renewable energy, European Union, SMEs firms

Highlights:

- ✓ Sustainable energies measures (EE and RE) are highly persistent at the firm level and across countries in the European Union.
- ✓ High complementarities between EE and RE practices are found. Also, European SMEs firms undertaking such measures are more likely to continue applying them in the future.
- ✓ EE strategies are influenced by cost saving and regulations, in contrast, RE are more linked to public support and environmental awareness.
- ✓ The drivers of EE and RE, in addition to their persistence and the complementarities between them, highlight the need to deploy an energy policy that jointly pursues EE improvements and the promotion of RE.

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1. Introduction

Recently the public policies that promoted the transition to a sustainable energy model have focused on two objectives: the promotion and diffusion of energy efficiency (hereafter EE) and the adoption new sources of renewable energy (hereafter RE) from green energy technologies. In the short term, public policies pursuing the reduction of the emission of greenhouse effect gases (hereafter GEG), primarily use regulations and financials tools, but, in the longer term, the most important determinants of success or failure in environmental protection are related to the development and more efficient spread of new technologies (Jaffe and Stavins 1994). Although, these goals are not independent and present significant synergies, the relationship between EE and RE has received limited attention from policy makers and academics, especially in empirical studies focused on the determinants of the environmental performance of European firms (IRENA 2015; Del Río, Peñasco, and Romero-Jordán 2016; Díaz-García, González-Moreno, and Sáez-Martínez 2015).

One key option for transitioning to a low-carbon energy model is to increase the share of RE sources, especially for electricity generation (Pfeiffer and Mulder 2013). Considering that SMEs are responsible for approximately 64% of industrial pollution in Europe (European Commission 2010), it is essential to design policies that facilitate the use of these technologies to reduce global GEG emissions (Popp, Hascic, and Medhi 2011). Following these lines, policymakers have increasingly supported the development of more efficient energy technologies and, especially in the diffusion of RE technologies (Mazzucato and Semieniuk 2018; Polzin et al. 2015).

Consequently, this empirical paper uses an extensive sample of European SMEs to analyse the drivers of both environmental strategies at firm level. Our starting point is that both EE and RE measures carried out by SMEs tend to increase the share of resource efficiency actions and reduce the total final energy consumption at country level. In this interpretation, EE and RE are the two main pillars of the sustainable energy policy. However, saving energy usage and promoting RE sources will lead to complex interactions that condition results depending on the characteristics of sectors and countries (Del Río González 2007).

Across the EU28, SMEs can make a relevant contribution towards that challenge since they are considered the backbone of Europe's economy. According to Eurostat's Structural Business Statistics Database, in 2015, European SMEs accounted for 99.8% of the business fabric, generating 66.8% of employment and 57.4% of added value (European Commission 2016). Furthermore, apart from being economically important, European SMEs are also important for the environment. In this field, European SMEs generate approximately 64% of the industrial pollution in Europe (European Commission 2010).

Over the last few years, several studies have analysed the role of barriers to the adoption of EE practices (Trianni, Cagno, and Farné 2016; Sorrell et al. 2000; Trianni, Cagno, and Worrell 2013; Rohdin, Thollander, and Solding 2007; Schleich and Gruber 2008) while research into the drivers of EE and RE seems to be less explored at both firm level, especially across SME firms (Costa-Campi, García-Quevedo, and Segarra-Blasco 2015; Horbach, Rammer, and Rennings 2012). Furthermore, mainly due to data restrictions, there are few analyses comparing different countries (Horbach 2016; Solnørdal and Foss 2018).

Starting from this evidence, one of the challenges is the need to explore the drivers of EE and RE in greater detail across European SME's. Hence, the present paper empirically analyses the main firm characteristics that drive the adoption of EE and RE practices to help policymakers to implement suitable instruments to promote them. The Flash Eurobarometer 426 "SMEs, resource efficiency and green market" permits an analysis of the determinants of both EE technologies and RE in SME firms across 28 different European countries. Since our final sample contains information on all the EU-28 members, the subsequent econometric analysis adopts two perspectives. First, an aggregate analysis is carried out for all the member countries; subsequently we distinguish three clusters of countries. The classification adopted is based on criteria related to bilateral trade flows between the EU country members, GDP per capita, and the innovation index elaborated by the European Innovation Scoreboard (European Commission, 2018). In the group termed 'Core countries' we include countries that enjoy higher levels of productivity, GDP per capita above the EU average, and are intensive in exports of high technological content; in the Mediterranean countries' cluster we include the four countries of Southern Europe, while in 'New EU countries' we include the located in Central and Eastern Europe countries that joined the EU during the first decades of the 21st century (see the country distribution in Table A.1).

Applying a biprobit model to take into account the synergies between undertaking a sustainable energy policy now and the probability that a firm continue adopting future actions related to the improvement of EE and RE our results suggest that sustainable energies (EE and RE) are highly persistent at the firm level and that there are high complementarities between both, as well as other resource efficient practices. Moreover, EE strategies seem to rely more on cost saving and regulations, in contrast, RE strategies are more linked to public support and environmental awareness. In some European countries, public support to promote RE have been very effective, however countries with the most ambitious programs of this type (Denmark, Germany and Spain) have experienced a remarkable increase in electricity costs (Green and Yatchew 2012).

The remainder of the paper is structured as follows. Section 2 presents the analytical framework regarding the main factors fostering EE and RE actions. Section 3 describes the data and variables and presents the empirical methodology. Section 4 shows the econometric results and, finally, section 5 provides the main conclusions.

2. Literature review: drivers of energy efficiency and renewable energies

2.1 Sustainable energy: an overview

The transition towards a more sustainable energy model requires a wide range of technically useful and economically appropriate measures that affect all stages of the energy supply chain (European Commission 2014). In this regard, public policies aimed at improving EE and the increasing participation of RE technologies in the energy mix are the two main lines of action.

We can consider that EE and RE are integrated into the more general concept of eco-innovation.[1] Nevertheless, defining EE is not a simple task. Our definition is that EE is the use of energy in an optimum manner to achieve the same service that might have been achieved less efficiently. In other words, EE refers to using less energy input to deliver the same service, but gains in the EE will result in an effective reduction in the energy price per unit, and as a result the total energy use should increase partially reducing the impact of the efficiency gain (i.e., “rebound” effect).[2] To overcome this situation and following the Flash Eurobarometer Survey 426 we interpret that the European SMEs carry-out EE actions when firms undertake energy-saving actions and reduce the total energy use (European Commission 2012).

On the other hand, we interpret RE as the actions that firms carry out to increase the use of solar, wind, geothermal, hydro, ocean and biomass energy sources. In the past four decades, solar and wind power systems have experienced rapid sales growth, declining

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[1] The Eco-Innovation Observatory (EIO 2013) defines eco-innovation as the “*the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land) and decreases the release of harmful substances across the whole lifecycle*”.

[2] Definitions of the “rebound” effect vary in the literature, and the empirical research found the size of the rebound effect is moderate. See a survey of the conceptual and empirical literature in Greening et al. (2000).

capital costs and costs of electricity generated, and have continued to improve their performance characteristics (Arent, Wise, and Gelman 2011). Furthermore, the evolution of fossil fuel prices and RE costs have headed in opposite directions and, consequently, have facilitated the development of new energy technologies. In addition, the growth of research activities in the field of sustainable technologies and the subsequent adoption by private firms have been supported by public energy policies that facilitate the rapid diffusion of RE sources.

According to the Flash Eurobarometer Survey 426 (FL426), European firms have several means at their disposal to improve their level of environmental management (Table 1). The survey considers that European SMEs have eight practices to be more resource efficient. Six of them are related to saving of supplies or materials and waste management — water saving, materials saving, waste management, sell scrap material to another firm, recycling or reusing material and waste, designing new products that are easier to maintain or reuse—; while the remaining two practices are related to saving energy usage and increasing the RE sources.[3] Hence, the empirical analysis is focused on deepening the drivers that affect EE and RE strategies in European SMEs. Furthermore, a relevant dimension of the work is to examine the complementarities that may exist between both sustainable energy actions and, also, between EE and RE actions and other resource efficient practices related to related to saving supplies or materials and waste management.

Most of SMEs firms are taking some actions to be more resource efficient (Table A.1). Specifically, the reduction of energy is the most prevalent action among SMEs across the EU-28, followed by other actions aimed at saving materials and minimising waste. In contrast, SMEs are less likely to be taking actions using predominantly RE. Regarding using RE, we see that few SME firms decide to implement it (14% and 19% in status *t* and status *t+2*). It is an incipient activity and still rare in European countries. This lack of motivation might be related to high switching costs that renewable technologies incur, which may impair the attractiveness of the sector for firms.

Furthermore, the moderate propensity of Mediterranean and Central and Eastern countries to invest in resource efficient practices and, especially, in EE and RE actions, reflects the weakness of their environmental awareness and eco-policies system at regional and country level in facilitating the implementation of green practices among

[3] Flash Eurobarometer 426 considers energy resources naturally derived directly or indirectly from the sun, or from other natural movements and mechanisms from the environment—wind power, solar energy, small hydropower and geothermal energy—including producing your own energy through solar panels, etc.

their local firms. Therefore, these data calls for an active and coordinated European energy policy to reduce internal differences among European countries. Country members are required to set up national objectives and sustainable energy programs; these objectives and the actions of each Member State should be coordinated with other members and evaluated by the European Commission to determine the likelihood of achieving the EU's overall objective of improving 20% improvement in EE levels by 2020 (European Council 2012). A new European energy policy must rest on a dual design that integrates and coordinates actions at the national level ("bottom-up") and collective action at the European level ("top-down"). The success of the future European energy policy will depend on how these two levels of government are supported and coordinated (Stern and Rydge 2012).

2.2 Drivers of energy efficiency and renewable energy

The literature contributions on eco-innovation and the impact of environmental policies on innovation decisions open a wider perspective than that exclusively focused on saving costs. The Porter and Linde (1995) contribution introduced a new approach based on the existence of a positive relationship between environmental policies and innovation that strengthen the product quality, cost savings, and in the end, the enterprise's competitiveness. This framework remarks that the progress in EE and RE has internal effects in terms of costs as well as external ones regarding the direct effect on emission reduction and climate change mitigation. Even though the design and implementation of diverse EE and RE encouragement policies from different government levels — European, state, regional and local— sustainable energies actions are still scarcely implemented by European SMEs. Because of this, it is crucial to improve such public policies effectiveness through a better understanding of the barriers to be tackled and the drivers to be promoted.

During last decades, a great effort has been made to identify the main barriers to EE and RE. In particular, many contributions have been focused on formulating a comprehensive taxonomy of the main barriers to EE (Sorrell et al. 2000; Sorrell, Mallett, and Nye 2011; Fleiter, Schleich, and Ravivanpong 2012). We note, for example, two recent survey of empirical studies on barriers to industrial EE by Trianni et al., (2016) and Cagno and Trianni (2013). However, too little research has dealt with the study of the drivers of sustainable energies actions and the complementarities between saving energy and using RE at the firm level. Most of the empirical contributions that we observe study the determinants of eco-innovation in general and establish a distinction according to the areas of impact, which allows the identification of the determinants of EE (Horbach, Rammer, and Rennings 2012; Horbach 2016; Costa-Campi, García-Quevedo, and

Segarra-Blasco 2015). In addition, mainly due to data restrictions, there are still few contributions which attempt to conduct a country comparison analysis among European SME (Horbach 2016; Solnørdal and Foss 2018).

Following Horbach (2008), we examine the drivers of EE and RE strategies from the perspective of the supply side, demand side, environmental policy, as well as the firms' structural characteristics and country factors in line with resource-based and evolutionary perspective approaches. Since eco-innovations are affected by the problem of double externality (Rennings 2000), the combination of the enviormental externality and knowledge market failures justifies the neoclassical approaches that emphasise the need for a regulatory push and pull stimulus to encourage their adoption. On the other hand, evolutionary approaches are more suitable for interpreting the relevance of the context in which environmental innovation emerge, and for emphasizing the importance of innovation systems, the dynamic interaction between different actors and the internal and external factors influencing the innovation process (Nelson and Winter 1982).

The main result in the recent literature on the determinants of eco-innovation is that eco-innovations are more dependent on regulation than are other innovations (Horbach 2016; Horbach, Rammer, and Rennings 2012; Del Río, Peñasco, and Romero-Jordán 2015). Additionality, an important contribution to the discussion was made by Kammerer (2009) and showed the need to distinguish between eco-innovations that target energy from others because regulation effects vary depending on the environmental area. For instance, Horbach et al., (2012) using a German sample examine the determinants of eco-innovations by type of environmental impact and show that regulation seems to be important for many environmental innovations but not specifically for reducing the use of energy. Similarly, Solnørdal and Foss (2018) in their recently systematic literature review on EE drivers find that firms assign less importance to regulation as an important driving factor for EE. In contrast, others authors show that regulations affect innovation behaviour that has the objective of reducing energy consumption (Veugelers 2012; Costa-Campi, García-Quevedo, and Segarra-Blasco 2015).

It is argued that a stable and consistent policy framework is required to create the conditions to implement RE technologies (De Vries and Verzijlbergh 2018; Foxon et al. 2005; del Río, Peñasco, and Mir-Artigues 2018). Along the same lines, the literature considers that public policies in the form of investment incentives (grants or low-interest loans), incentive taxes and tariffs, mainly feed-in-tariffs, voluntary programs and compulsory renewable targets are relevant to explaining the RE development (Gan, Eskeland, and Kolshus 2007; Wüstenhagen and Bilharz 2006; Johnstone, Haščič, and Popp 2010). Although public policies are a major driver in the development of renewables, some authors point out that different types of policy instruments are effective for different RE sources (Johnstone, Haščič, and Popp 2010; António Cardoso Marques and Fuinhas 2012).

While regulation and public policies seem to be necessary to overcome the double externality problem, there is no strong empirical evidence that market pull supports eco-innovation (Del Río, Peñasco, and Romero-Jordán 2016; Jaffe and Palmer 1997; Rubashkina, Galeotti, and Verdolini 2015; Ambec et al. 2013; Horbach, Rammer, and Rennings 2012). The expectation of a future demand, created by environmentally conscious customers, plays a key role in eco-innovations if the product or service delivered adds value to the customer. Similarly, Hrovatin, Dolšak, and Zorić (2016) show that managers' expectations of future demand only impact EE investments, while investments in RE technologies are more dependent on managers' anticipation of the future business condition of the firm.

Furthermore, supply factors play a relevant role in eco-innovation. Mostly they are linked to the development of technological capabilities, which can be increased through R&D investments or activities, but also rely on organizational capabilities and organizational innovations. In this regard, internal R&D seems to be particularly important for material and energy savings. This might be expected as material and energy savings often stem from changes of the individual production process. Several empirical studies stress that cost savings are determining factors of clean technologies and EE actions (Horbach, Rammer, and Rennings 2012; Horbach 2016).

Finally, empirical evidence also emphasizes that a firm's profile is a key factor when it comes to introducing innovations aimed at improving EE and RE levels. The group of drivers considered to be as firm-specific factors includes all those firm characteristics, such as size, location, sector, and age which usually affect together with other more relevant determinants, the innovativeness of a firm (Barbieri et al. 2016).

3. Data and methodology

3.1 Data

The empirical part of the paper relies on the Flash Eurobarometer Survey 426 (FL426) on *"Small and Medium Enterprises, Resources Efficiency and Green Markets, wave 3"* addressed to more than fifteen thousand managers of European firms between the 1st and 18th of September 2015.

One of the main strengths of our dataset from the Flash Eurobarometer Survey 426 (FL426) is that it includes three dimensions, namely country, sector, and firm size. Most environmental empirical datasets offer aggregate information at country level, so having three dimensions in the same database allow researchers many possible views and perspectives on the data. On the other hand, one of the main drawbacks of the Flash Eurobarometer Survey 426 data is that it is a cross-sectional dataset. This makes the simultaneity problem almost unavoidable and is a common problem for all studies using Flash Eurobarometer datasets (Marin, Marzucchi, and Zoboli 2015; Hoogendoorn, Guerra, and van der Zwan 2015). After a cleaning process[4], our final sample consists of 8,213 SMEs located in the 28 EU member countries.

Considering that the levels of the EE and the weight reached by RE sources differ between the SMEs, and, between European countries, our empirical analysis adopts a double perspective. Accordingly, to examine the differences among European countries in some depth, we classify the EU28 countries into three clusters: Core countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Sweden, the Netherlands, the United Kingdom), Mediterranean countries (Greece, Italy, Portugal, and Spain), and New EU countries (Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia).

3.2 Descriptive statistics

Our data set offers evidence highlighting that the patterns adopted by SMEs of each country differ significantly, both in the current implementation of EE and RE actions and in the future decisions to adopt them (Tables 1 and 2). Table 1 shows that 43% of European SMEs saving energy status in year *t* intend to remain EE in the future, while only 20% shift to become non-EE. In addition, 36% of European SMEs do not perform energy saving actions, among which 28% of sample firms do not consider performing energy saving actions, while the remaining 8% only do so if they intend to reduce their energy consumption during the next two years.

Table 1 shows a transition matrix where the probabilities of changing energy saving consumption status between year *t* and year *t+2* are moderate. European SMEs exhibit persistent obstacles to saving on energy consumption. Regarding differences between country groups, for the Central and Eastern Country group, the share of firms that expect

[4] The cleaning process consisted of restricting our sample only to SMEs located in EU28 (the retail sector is not incorporated in the sample) as well as discarding observations with missing values for the relevant variables.

to develop saving energy strategies is lower, and the New EU members group shows the lowest capacity to engage in saving energy actions.

Table 1. Save energy present decisions vs. future decisions

		Status in t+2			
		Not saving energy		**Saving energy**	
	Status in t	**Firms**	**(%)**	**Firms**	**(%)**
Total	Not saving	2,365	28.80	638	7.77
	Saving	1,654	20.14	3,556	43.30
Core Countries	Not saving	742	23.07	252	7.84
	Saving	730	22.70	1,492	46.39
Mediterranean Countries	Not saving	399	31.95	111	8.89
	Saving	175	14.01	564	45.16
New Countries	Not saving	1,224	32.66	275	7.34
	Saving	749	19.98	1,500	40.02

Source: Flash Eurobarometer 426, own calculations

Table 2 presents the changes of RE status. The resistance towards giving greater prominence to renewable energy sources is reflected in the more static transition matrix shown. Three out of four European SMEs do not use renewable energy sources, nor do they intend to incorporate them in the short term, while only 18% of firms aim to increase the use of renewable energy sources. On this point, we observe sharper differences between the three country clusters. In Core country cluster, 23.75% of firms plan to carry out RE actions; in Mediterranean countries, this reduces to 19.14%; while in Central and Eastern countries the corresponding figure is a mere 14.57%.

Table 2. Use of renewable energy present decisions vs. future decisions

		Status in t+2			
		Not using RE		**Using RE**	
	Status in t	**Firms**	**(%)**	**Firms**	**(%)**
Total	Not using	6,185	75.31	890	10.84
	Using	479	5.83	659	8.02
Core Countries	Not using	2,165	67.32	386	12.00
	Using	287	8.92	378	11.75
Mediterranean Countries	Not using	969	77.58	137	10.97
	Using	41	3.28	102	8.17
New Countries	Not using	3,051	81.40	367	9.79
	Using	151	4.03	179	4.78

Source: Flash Eurobarometer 426, own calculations

The main features of SME firms in EU28 distinguishing the three country clusters that we consider in this study (Table A.1):

- ✓ On average, the most important reason for SME firms to take actions to become more resource efficient is cost saving (60%). A less important reason is to catch up with the main competitors who have already taken green actions.

- ✓ Firms belonging to Core countries tend to anticipate future changes in legislation and sell more of their products to public administration than do Mediterranean and New member countries.
- ✓ In New EU members, firms are younger than in Core and Mediterranean countries.
- ✓ Core countries have the highest level of CO^2 emissions per capita and their inhabitants have a greater environmental awareness being more likely to buy ecological goods, even if they have a higher price.

3.3 Methodology and variables

To consider the possible complementarity between current EE and RE actions be more resource efficient and those planned them over the next two years, we apply a bivariate probit procedure. Hence, we consider a simultaneous model where the present actions to be more EE and the future plans are interrelated.

The general specification for EE actions is the following:

$$EE\ now_i = x_i\beta_{11} + \varepsilon_{1i} \quad (1a)$$

$$EE\ future_i = x_i\beta_{21} + \varepsilon_{2i} \quad (1b)$$

Whereas the general specification for RE actions is the following :

$$RE\ now_i = x_i\beta_{31} + \varepsilon_{3i} \quad (2a)$$

$$RE\ future_i = x_i\beta_{41} + \varepsilon_{4i} \quad (2b)$$

Equation (1a) and (2a) estimate the probability that a firm undertakes a resource efficiency practice, EE or RE.[5] Equations (1b) and (2b) determine the probability that a firm is planning to implement some sustainable energy practices over the next two years (EE or RE). All dependent variables are dummy variables that take the value 1 if the firm engages EE or RE at the present or in the future respectively.

As explanatory variables to examine current EE and RE practices, we include different factors in order to calibrate the complementarity effects between both practices, the complementarity effects with other resource efficient actions, the role of policy influences, market pull, technology push and a set of control variables related to firm and

[5] See Table A.1 for the variable definitions.

country characteristics. As drivers for future actions, apart from including the complementary effect between both practices and the control variables, we introduce the lag of the dependent variable to capture any possible persistence in the decision to undertake resource-efficient actions as well as a set of variables related to resource actions returns.

We assume that ε_i are independently and identically normally distributed residuals. The parameter ρ identifies the correlation between the disturbances, and accounts for omitted or unobservable factors that simultaneously affect the decision to undertake EE and RE practices and the likelihood of planning them over next two years. Our results show that the coefficient ρ is significantly different to 0 in both practices and in all clusters (except for the case of RE in the Mediterranean cluster). This suggests that the bivariate probit methodology is more efficient than the estimation of two separate probits.

4. Results

We are interested in analyzing, from a temporal and geographic perspective, the factors that affect a firm's ability to undertake measures related to saving energy or promoting RE sources (Table 3). From the temporal perspective, we distinguish between implementing sustainable energy measures now and the capacity to plan additional energy actions in the proximate future and consider their possible complementarities. From the geographic perspective, we are interested in examining the differences that might exist between the three clusters of EU country members considered in this paper, Core countries, Mediterranean countries, and the New EU members.

An increasing number of empirical publications in the innovation literature devote attention to analysing the role of persistence; however, as far as we are concerned, persistence has not previously been addressed in the literature on drivers of resource efficiency practices such as EE or RE actions.[6] In this sense, regarding the EE practices that firms are planning to implement in the next two years, our results reveal that engaging in EE actions during the previous years has a positive relationship with the probability of

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[6] Economic theory provides at least three potential explanations for why innovation might demonstrate state dependence over time. First, success breeds success (successful innovations positively affect the conditions for subsequent innovations, providing prosperous innovators with higher market power for an extended period). Second, dynamic increasing returns (firms learn by innovating and develop new organizational competencies along the technological trajectory). And finally, sunk costs in R&D investments (R&D investments over time generate a stock of physical and knowledge capital that in the longer term can be used in innovative activities and contribute to a more or less continuous flow of innovations) (Peters 2009; Raymond et al. 2010).

engaging in EE practices in the future. Indeed, the estimation results show that this persistence is present in all country clusters. Looking now at the drivers of designing future RE actions, our results highlight that the coefficient of the lagged dependent variable is also positive and significant for the whole sample, revealing that engaging in RE strategies during the previous year has a positive effect on the probability of being a green innovator in terms of RE actions in the future. The results also point to the possible existence of complementarities between EE and RE practices across European SMEs, an increased use of RE leading to an increased use of EE and vice versa. To determine whether there is a significant difference in planning future EE and RE strategies by adopting in the present only EE, only RE, or a joint EE and RE strategy, we analyse the complementarities between the two sustainable energy practices using the theory of supermodularity. Our results show that implementing EE and RE in the present have a significant positive effect on the probability of planning future EE and RE strategies for all cases considered, except for Mediterranean countries where this positive relationship is not significant in EE strategy.[7]

After estimating the effects of persistence and complementarities on the probability that European SMEs perform EE and RE actions, we also estimate whether the expectations of SME managers are related to the likelihood that SMEs will perform these eco-innovation actions. Finally, by controlling the firm profiles and the country environmental frame, we consider some characteristics of the firm, such as its size and age; and the role of three aggregate environmental indicators at country level —CO^2 emissions per capita, willingness to pay for ecological products, and renewable sources growth.

Our results show that managers' satisfaction with the returns on the investments in resource efficiency practices, and their expectation of future competitive advantage or business opportunity seem to have a positive and significant effect in implementing EE and RE practices in the future. On the other, firms that invest a significant amount of money in resource efficiency practices are more likely to implement RE actions. In contrast, no significant effect is observed in implementing EE actions. In general, in line with the literature, size is found significant with a positive effect on EE adoption, but in contrast, it does not seem to have a significant effect on RE technologies (Hrovatin, Dolšak, and Zorić 2016; Solnørdal and Foss 2018), while age plays an ambiguous role. Finally, the aggregate determinants seem to be not significant in explaining either the probability of planning future EE or RE strategies.

[7] Empirical results of complementaritarities text are available upon request.

Regarding the drivers of currently implementing EE or RE practices, public policies in terms of firm sensitivity towards legislation and public incentives are strongly related to promoting both actions among European SMEs, a result that coincides with the results of other studies (Foxon et al. 2005). Also, market push by customers and providers is a significant driver of incentivizing firms to undertake EE practices, but this factor did not seem to be relevant in determining RE strategies. Instead, public demand is a significant driver of incentivizing firms to implement RE. In relation to technology push factors, and in line with the literature, cost saving and catching up with main competitors are significant drivers for undertaking EE practices while do not seem to have significant influence on RE. Other drivers considered as strategic for increasing EE and RE actions are the presence within the company of people with great ambition and sensitivity to the environment as a top priority for the firm. Related to internal drivers, we found that EE is closely related to firm characteristics such as size and age. Both variables have a positive and significant effect for EE actions, indicating that small and young firms find more barriers than their counterparts in carrying out EE actions. In contrast to EE strategies, internal characteristics such as the size and age of the firms are not decisive in implementing RE actions.

Furthermore, EE and RE are closely related to other eco-efficiency actions. Practices like saving water, minimizing waste and designing products that are easier to maintain, repair and reuse show some complementarities with both activities undertaken. Finally, we observe that aggregate environmental concerns are incentives for a widespread use of EE, but not for RE strategies.

Table 3
Bivariate probit models

	Energy efficiency (EE)				Renewable energies (RE)			
	Total	**Core**	**Mediterranean**	**New EU**	**Total**	**Core**	**Mediterranean**	**New EU**
	FUTURE							
Persistence								
EE (present)	1.799***	1.599***	2.014***	1.853***				
	(0.0458)	(0.0795)	(0.118)	(0.0642)				
RE (present)					2.007***	1.990***	1.411	1.968***
					(0.113)	(0.164)	(1.402)	(0.175)
Complementarity								
EE (future)					0.793***	0.944***	0.761***	0.690***
					(0.0423)	(0.0698)	(0.122)	(0.0629)
RE (future)	0.664***	0.845***	0.524***	0.548***				
	(0.0440)	(0.0672)	(0.106)	(0.0705)				
Resource actions returns								
Satisfied	0.149***	0.178***	0.118	0.141**	0.175***	0.179**	0.219*	0.164**
	(0.0325)	(0.0523)	(0.0847)	(0.0482)	(0.0382)	(0.0572)	(0.104)	(0.0601)
Intensity	-0.0768	-0.0631	-0.108	-0.0498	0.200***	0.159	0.186	0.227**
	(0.0506)	(0.0815)	(0.131)	(0.0750)	(0.0558)	(0.0841)	(0.160)	(0.0848)
Competitive advantage	0.0819*	0.0395	-0.0779	0.181***	0.103*	0.0539	0.149	0.166*
	(0.0374)	(0.0575)	(0.0999)	(0.0572)	(0.0426)	(0.0621)	(0.113)	(0.0676)
Firm characteristics								
Size	0.0182	0.0520**	0.0135	-0.003	-0.0174	-0.0458*	0.0177	-0.00195
	(0.0109)	(0.0177)	(0.0277)	(0.0162)	(0.0125)	(0.0181)	(0.0390)	(0.0204)
Age	-0.0143	-0.0144	-0.0253	-0.0133	-0.00927	-0.0174	0.00942	0.0238
	(0.0192)	(0.0266)	(0.0550)	(0.0324)	(0.0225)	(0.0294)	(0.0781)	(0.0401)

Aggregate determinants								
CO^2	-0.0520	0.0933**	-0.141**	-0.0558	-0.0847	-0.120**	0.280***	-0.0870
	(0.0491)	(0.0342)	(0.0525)	(0.0502)	(0.0544)	(0.0434)	(0.0657)	(0.0547)
Willingness pay	0.00123	0.0966***	0.0699***	0.00441	0.0187	-0.0250	-0.0592*	0.0173
	(0.0427)	(0.0150)	(0.0127)	(0.0435)	(0.0494)	(0.0189)	(0.0232)	(0.0496)
RE_Growth	0.0717	0.0507***	-0.0180	0.0796	0.0439	0.00115	-0.0568	0.0422
	(0.115)	(0.00441)	(0.0210)	(0.117)	(0.133)	(0.00525)	(0.0393)	(0.133)
Constant	-1.394	-10.99***	-4.946***	-1.642	-2.772	1.288	1.058	-2.706
	(3.451)	(1.541)	(0.765)	(3.525)	(4.012)	(1.952)	(1.358)	(4.038)
					PRESENT			
Other resource efficient practices								
Saving water	0.948***	0.824***	0.899***	1.074***	0.275***	0.351***	0.111	0.213**
	(0.0393)	(0.0614)	(0.102)	(0.0595)	(0.0425)	(0.0587)	(0.131)	(0.0747)
Energy efficiency					0.326***	0.437***	0.372*	0.226*
					(0.0526)	(0.0778)	(0.164)	(0.0890)
Renewable energy	0.288***	0.387***	0.213	0.168				
	(0.0580)	(0.0812)	(0.140)	(0.104)				
Saving materials	0.425***	0.266***	0.433***	0.545***	-0.0256	-0.0127	-0.0672	0.0419
	(0.0370)	(0.0595)	(0.0951)	(0.0560)	(0.0463)	(0.0637)	(0.128)	(0.0819)
Minimizing waste	0.371***	0.452***	0.356***	0.325***	0.196***	0.117	0.380**	0.201*
	(0.0384)	(0.0620)	(0.0931)	(0.0586)	(0.0491)	(0.0725)	(0.121)	(0.0830)
Selling scrap	0.0407	0.0745	0.159	-0.0270	-0.00646	-0.0179	-0.0391	0.00269
	(0.0407)	(0.0646)	(0.102)	(0.0626)	(0.0418)	(0.0594)	(0.164)	(0.0699)
Recycling	-0.0113	0.0621	0.0435	-0.103	0.164***	0.109	0.191	0.237***
	(0.0373)	(0.0585)	(0.0884)	(0.0587)	(0.0400)	(0.0571)	(0.159)	(0.0658)
Designing products	0.195***	0.259***	0.114	0.172*	0.264***	0.263***	-0.219	0.410***
	(0.0428)	(0.0646)	(0.101)	(0.0694)	(0.0420)	(0.0573)	(0.150)	(0.0696)
Policy drivers								
Anticipation legislation	0.217***	0.241**	0.342*	0.152	0.135*	0.119	0.352*	0.140
	(0.0536)	(0.0772)	(0.157)	(0.0859)	(0.0547)	(0.0736)	(0.167)	(0.0940)
Public support	0.297***	0.329***	0.226	0.294***	0.239***	0.290***	-0.228	0.307***
	(0.0501)	(0.0723)	(0.124)	(0.0858)	(0.0485)	(0.0641)	(0.179)	(0.0852)
Market pull drivers								
Customers suppliers	0.187***	0.0895	0.275*	0.256***	0.00618	0.0328	-0.157	0.0480
	(0.0425)	(0.0624)	(0.108)	(0.0701)	(0.0468)	(0.0643)	(0.151)	(0.0814)
Public demand	0.0406	0.134*	-0.150	0.00999	0.0851*	0.0791	0.0580	0.114
	(0.0367)	(0.0565)	(0.0936)	(0.0575)	(0.0396)	(0.0547)	(0.115)	(0.0692)
Technology push drivers								
Cost saving	0.603***	0.586***	0.614***	0.619***	0.0407	-0.0568	0.238	0.0930
	(0.0337)	(0.0542)	(0.0840)	(0.0514)	(0.0429)	(0.0609)	(0.122)	(0.0715)
Competitors	0.246***	0.107	0.0880	0.409***	0.0994	0.133	-0.213	0.114
	(0.0611)	(0.115)	(0.125)	(0.0881)	(0.0646)	(0.101)	(0.227)	(0.0965)
Environment priority	0.428***	0.438***	0.442***	0.399***	0.296***	0.413***	0.264	0.102
	(0.0376)	(0.0595)	(0.0895)	(0.0587)	(0.0400)	(0.0565)	(0.158)	(0.0694)
Firm characteristics								
Size	0.0620***	0.0786***	0.0285	0.0628***	0.0170	-0.0271	0.0696	0.0553*
	(0.0118)	(0.0187)	(0.0293)	(0.0182)	(0.0134)	(0.0193)	(0.0389)	(0.0228)
Age	0.0702***	0.0702*	0.0440	0.0706	0.0241	0.0224	0.131	-0.00312
	(0.0211)	(0.0290)	(0.0579)	(0.0364)	(0.0228)	(0.0298)	(0.0751)	(0.0426)
Aggregate determinants								
CO^2	0.129*	0.00136	-0.0307	0.157**	0.121	-0.153***	0.0265	0.154
	(0.0502)	(0.0383)	(0.0588)	(0.0522)	(0.0850)	(0.0375)	(0.0776)	(0.0871)
Willingness pay	-0.0875	0.000275	0.0246	-0.107*	0.117	-0.0532***	-0.0484**	0.0891
	(0.0460)	(0.0176)	(0.0139)	(0.0480)	(0.0736)	(0.0157)	(0.0180)	(0.0752)
RE growth	-0.243	0.000921	-0.0446	-0.303*	0.284	-0.0345***	0.0701	0.201
	(0.124)	(0.00523)	(0.0249)	(0.130)	(0.200)	(0.00486)	(0.0420)	(0.205)
Constant	5.052	-1.744	-2.715**	6.632	-12.88*	4.421**	0.193	-10.63
	(3.747)	(1.786)	(0.865)	(3.918)	(5.924)	(1.615)	(1.086)	(6.078)
Rho (ρ)	-0.648***	-0.631***	-0.641***	-0.648***	-0.475***	-0.621***	0.198	-0.426***
	(0.0468)	(0.0758)	(0.128)	(0.0658)	(0.0859)	(0.165)	(0.744)	(0.111)
Log-likelihood	-7617.7	-2973.3	-1184.2	-3401.7	-5789.7	-2692.9	-835.7	-2180.5
Wald test of $\chi 2$	6431.5	2318.6	1113.8	3148.5	2571.8	1418.3	214.5	887.3
	(000)	(000)	(000)	(000)	(000)	(000)	(000)	(000)
Observations	8,213	3,216	1,249	3,748	8,213	3,216	1,249	3,748

Estimations control for country and sectors, *; **; *** indicate levels of significance equal to 10, 5 and 1 %. Robust standard errors in parentheses.

Looking now at the regressions for country clusters, the results for future actions highlight that engaging in EE actions now increases the probability of European SMEs engaging both eco-innovative practices in the future in all country groups. In contrast, for the case of RE actions, this persistence is only present for Core and New EU members. The results of the estimations also reveal a tighter complementary with EE and RE practices in all of the clusters examined. Moreover, firms that report high self-perceived resource investment profitability are more likely to implement new sustainable energy practice in the future, especially in the Core and New member clusters. New members firms that have better environmental management are more likely to undertake future EE and RE than are Core or Mediterranean countries.

For internal factors, firm size has a positive and significant coefficient only for Core countries when EE in the future is analysed, and a negative and significant effect on RE strategy. Firm age, however, has not been found to be significant in any cluster. Finally, we observe some differences regarding the results for aggregate factors between clusters. In Core countries. as we expected, greater environmental concerns and higher CO_2 emissions increase the propensity to implement EE practices in the future. In contrast, and in line with Marques et al. (2010), greater amounts of CO_2 in Mediterranean countries and more environmental concerns in New EU members do not imply a greater EE commitment.

Considering the drivers of currently implementing EE or RE practices, public policies play a key role in promoting both strategies. Splitting the sample into three clusters, we observe that all of them benefit from both instruments when undertaking EE actions. On the other hand, investments in RE technologies are dependent on public support for Core and New EU members and dependent on regulations on Mediterranean group.

Market push by the expectation of demand for resource efficiency actions is a significant driver of incentivizing firms to undertake EE practices, although this need to be nuanced when we divide the sample, since only Mediterranean and New EU members show a positive and significant relationship. In contrast, demand for green activities on RE actions have no effect in any country cluster. Moreover, having public institutions as clients seem to be influential for Core firms when implementing EE actions and for New Members when carry out RE actions. In relation to technology push factors, cost saving is a significant driver for undertaking EE practices in all country clusters considered, but not for RE (except for the Mediterranean countries). Considering the environment as a top priority for the firm increases the likelihood EE and RE actions, mainly for Core and Mediterranean countries.

Related to firm characteristics, firm size has positive and significant coefficients for EE practices for Core and New countries. However, when RE actions are considered the results show that firm size is a significant driver for Mediterranean and New members. Firm age has only a statistically significant and positive impact on the likelihood of implementing both resource efficiency practices in Core countries.

5. Conclusions

EE and the adoption of RE sources are two of the most effective ways to ensure and reduce greenhouse gas emissions. In order to achieve the objectives of the EU 20/20/20 and comply with the Paris Agreement on Climate Change and with the 2030 Union's energy and climate framework, it is essential to reduce the obstacles faced by more than 20 million European SMEs in carrying out improvements in the provision and consumption of energy. The low percentage of European SMEs that carry out EE actions and promote the most environmentally friendly energy can only be explained by the presence of important deterring barriers. These obstacles are related to the intrinsic characteristics of European SMEs—financial restrictions, limited cooperation with external partners, development of short-term strategies—and also with the limitation of energy public policies among EU countries which include a lack of synchronization between energy national systems, little flexibility in incorporating renewable energy technologies, and an energetic energy policy that does not facilitate the development of long-term energy strategies among SMEs.

In this study, we provide an overview of European SMEs attitudes to reducing energy costs and increasing the weight of sustainable energy sources. Despite the importance of implementing sustainable energy measures for climate change mitigation, the determinants of EE and RE across European SMEs level have barely been examined. Using a sample of 8,213 European SMEs taken from data of the Flash Eurobarometer 426, we explore from a temporal and geographic perspective, the influencing factors in the adoption of EE and RE actions and their potential complementarities.

The empirical evidence in this paper shows differences between the drivers of RE and EE measures and across country clusters. On the one hand, implementing EE practices in the present are associated mainly with regulatory and technology push factors. For EE strategies future regulations, public support, cost saving, and environmental awareness are the main motivations. Across countries, we observe that Core and Mediterranean countries benefit from firms anticipating future changes in legislation. In contrast, because of public support, New EU members are more likely to implement EE. Firms' characteristics such as size and age are also key factors when it comes to introducing EE measures. On the other hand, RE is more linked to public support and environmental awareness of the firms. Specially, public incentives play a crucial role among Core and New EU countries.

The econometric estimations also show that EE and RE may complement each other. However, this positive link between energy savings and the incorporation of RE technologies only takes place among the firms in the Core countries. Furthermore, sustainable energy practices are closely related to the ability of firms to undertake other measures for managing resources more efficiently such as saving water, minimizing waste or designing new products that are easier to maintain, repair or reuse.

Regarding the ability of European SMEs to implement future strategies related to EE and RE, it is worth mentioning the strong temporal persistence between the realization of sustainable energy measures and the likelihood that the firms are planning to continue carrying out these actions. Furthermore, saving energy and RE exhibit strong synergies in the sense that firms performing actions related to RE are more likely to develop energy saving strategies in the future, while firms carrying out saving energy actions also are more likely to promote RE in the future.

These results highlight the need to indicate that European SMEs are likely to jointly undertake EE and RE actions by generating synergies to increase both the share of RE and the improvement of energy use. This implies a need to deploy an energy policy that jointly pursues EE improvements and the promotion of RE, and, especially to reduce the barriers encountered by European SMEs. The design of an energy policy based on a set of instruments that encourages European SMEs to carry out EE and RE is, above all, necessary in environments with high externalities and low initial efficiency of energy technologies.

Finally, the analysis presented has provided useful additional results on the determinants of EE and RE in European SMEs. Nevertheless, it is important to highlight some limitations of the paper that could be the object of fruitful future research. The database only allows us to identify whether or not the firm undertakes EE or RE actions, but we cannot capture which different types of EE and RE actions are implemented, only the intensity of such actions. Since factors determining the decision to undertake EE and RE actions and the EE and RE types or intensity might differ, we encourage further research in this area. On the methodological front, our cross-section analysis could be further extended by incorporating temporal dynamics in the analysis as data become available. Ideally, such longitudinal information would allow researchers to detect the decision and the level of EE and RE practices over time and to understand why some firms embrace green technologies and actions early, while other firms do so much later (or not at all), and how their status changes over time.

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Appendix

Appendix 1. Variables definitions

Table A.1
Variables, definitions and descriptive statistics (mean)

Dependent variables	Definition		Total	Core	Mediterranean	New members
Saving energy (EE)	Dummy variable that takes the value 1 if the firm undertakes energy saving actions, and 0 otherwise.	Present	0.6344	0.6909	0.5917	0.6001
		Future	0.5107	0.5423	0.5404	0.4736
Renewable energies (RE)	Dummy variable that takes the value 1 if the firm undertakes renewable energy actions, and 0 otherwise.	Present	0.1386	0.2068	0.1145	0.0881
		Future	0.1887	0.2376	0.1914	0.1457
Drivers of EE and RE	**Definition**		**Total**	**Core**	**Mediterranean**	**New members**
Other resource efficient practices						
Water saving	Dummy variable that takes the value 1 if the firm undertakes water saving actions, and 0 otherwise.		0.4441	0.4596	0.4147	0.4405
Material saving	Dummy variable that takes the value 1 if the firm undertakes material saving actions, and 0 otherwise.		0.5866	0.6247	0.5653	0.5611
Waste management	Dummy variable that takes the value 1 if the firm undertakes waste management practices, and 0 otherwise.		0.5802	0.6925	0.5156	0.5053
Selling scrap	Dummy variable that takes the value 1 if the firm sells its scrap material to another firm, and 0 otherwise.		0.3135	0.3364	0.3010	0.2980
Recycling	Dummy variable that takes the value 1 if the firm recycles by reusing material or waste within the firm, and 0 otherwise.		0.3850	0.4636	0.4532	0.2948
Designing products	Dummy variable that takes the value 1 if the firm designs products that are easier to maintain or reuse and 0 otherwise.		0.2404	0.2761	0.2826	0.1956
Resource actions returns						
Satisfied	Dummy variable that takes the value 1 if the firm considers fairly or very satisfied with the return on the investments in measures to improve resource efficiency and 0 otherwise.		0.4894	0.5420	0.5028	0.4397
Intensity	Dummy variable that takes the value 1 if the firm investment share on turnover is greater than 5% and 0 otherwise.		0.0996	0.1008	0.0945	0.1003
Competitive advantage	Dummy variable that takes the value 1 if the firm considers the creation of a competitive advantage or business opportunities as the main reason of taking eco-efficiency actions, and 0 otherwise.		0.2109	0.2397	0.2082	0.1870
Policy drivers						
Anticipation legislation	Dummy variable that takes the value 1 if the firm considers the anticipation of future changes in legislation as the main reason of taking eco-efficiency actions, and 0 otherwise.		0.1243	0.1570	0.0849	0.1094

Public support	Dummy variable that takes the value 1 if the firm considers financial and fiscal incentives or other forms of public support as the main reason of taking eco-efficiency actions, and 0 otherwise.	0.1520	0.1975	0.1385	0.1174
Market pull drivers					
Customers and suppliers	Dummy variable that takes 1 if the firm considers demand from customers and providers as the main reason of taking eco-efficiency actions, and 0 otherwise.	0.2094	0.2540	0.2074	0.1718
Public demand	Dummy variable that takes 1 if the firm sells its products or services to public institutions, and 0 otherwise.	0.3225	0.3666	0.2906	0.2954
Technology push drivers					
Cost saving	Dummy variable that takes 1 if the firm considers cost savings as the main reason of taking eco-efficiency actions, and 0 otherwise.	0.6093	0.6362	0.6245	0.5811
Competitors	Dummy variable that takes 1 if the firm considers catching-up with main competitors as the main reason of taking eco-efficiency actions, and 0 otherwise	0.0886	0.0637	0.1153	0.1011
Environment priority	Dummy variable that takes 1 if the firm considers the environment is one of the firm's top priority, and 0 otherwise.	0.3579	0.3760	0.3739	0.3370

Control variables	Definition	Total	Core	Mediterranean	New members
Firm characteristics					
Firm size	Number of employees in the firm (in log).	47.006	49.908	41.518	46.336
Firm age	Age of the firm in years (in log).	23.736	30.039	24.812	17.970
Sector	Dummy variable that takes 1 if the firm belongs to:	0.3278	0.2671	0.3851	0.3607
	Industry activities	0.4740	0.5457	0.4404	0.4237
	Manufacturing				
	Services	0.1982	0.1872	0.1745	0.2156
Country dummies	EU28 countries. Core countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Sweden, the Netherlands, the United Kingdom. Mediterranean countries: Greece, Italy, Portugal and Spain). New EU countries: Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.				
Aggregate determinants					
CO^2	CO^2 emissions per capita in EU countries during 2012.	7.3993	8.4564	6.2887	6.8623
Willingness pay	Importance of willingness to buy environmentally friendly products even if they cost a little bit more, share of "total agree" in % during 2014.	76.208	82.708	68.355	73.249
RE growth	Rate growth of share of RE in gross final energy consumption by country during the period 2005-2016.	0.0935	0.1327	0.0908	0.0735

Note: dependent variables are expressed in present (period t) and planning actions (period t+2)
Source: Flash Eurobarometer 426 and EUROSTAT own calculations