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Drivers for energy efficiency and their effect on barriers: empirical evidence from Italian manufacturing enterprises

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Abstract Industrial activities are responsible for a significant share of both global delivered energy demand and CO_2 emissions. Hence, a widespread adoption of energy-efficient technologies and practices represents a crucial means for sustainable production. Adopting a novel framework of drivers for energy efficiency describing the effect of drivers on barriers in the decision-making process steps and able to account for the nature of drivers and the stakeholders responsible for their promotion, we have performed an exploratory investigation into 61 manufacturing small- and medium-sized enterprises in Northern Italy. Our findings have highlighted the importance of information and economic drivers, showing the need for enterprises to be supported not only by public institutions but also by external stakeholders involved in the supply of energy-efficient technologies and practices such as industrial associations and groupings, as well as service and technology suppliers. Moreover, our study has highlighted an almost equal relevance of both internal and external drivers. According to our findings, the increase of awareness—generating the interest to energy issues and stimulated both by external and internal stakeholders—as well as financial issues have emerged as the most critical in the decision-making process to adopt an energy-efficient measure. A preliminary comprehension of the mechanisms relating drivers to barriers in the decision-making process brought additional value to the study, highlighting the most effective and specific means to overcome the existing barriers. We have also explored the effect of several firm characteristics, such as firm size and energy intensity offering suggestions for industrial decision-makers as well as policy-makers.

Keywords Energy efficiency · Drivers · Barriers · Decision-making · Manufacturing sector · Small- and medium-sized enterprises

The original version of this article was revised: The given name of one of the authors was incorrectly captured as "Vincenzo" when it should be "Giovanni".

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Introduction

According to the most recent European Directive on Energy Efficiency (European Council 2012), future domestic and international policies should be focused on boosting the deployment of the so-called energy efficiency measures (EEMs) within the industrial sector. Hence, tackling the most critical barriers hindering their adoption is becoming crucial, as also revealed by recent studies (see, e.g. Catarino et al. 2015; Rohdin and Thollander

Drivers for energy efficiency and their effect on barriers: empirical evidence from Italian manufacturing enterprises

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Abstract

Industrial activities are responsible for a significant share of both global delivered energy demand and CO_2 emissions. Hence, a widespread adoption of energy-efficient technologies and practices represents a crucial means for sustainable production. Adopting a novel framework of drivers for energy efficiency describing the effect of drivers on barriers in the decision-making process steps and able to account for the nature of drivers and the stakeholders responsible for their promotion, we have performed an exploratory investigation into 61 manufacturing small- and medium-sized enterprises in Northern Italy. Our findings have highlighted the importance of information and economic drivers, showing the need for enterprises to be supported not only by public institutions but also by external stakeholders involved in the supply of energy-efficient technologies and practices such as industrial associations and groupings, as well as service and technology

suppliers. Moreover, our study has highlighted an almost equal relevance of both internal and external drivers. According to our findings, the increase of awareness—generating the interest to energy issues and stimulated both by external and internal stakeholders—as well as financial issues have emerged as the most critical in the decision-making process to adopt an energy-efficient measure. A preliminary comprehension of the mechanisms relating drivers to barriers in the decision-making process brought additional value to the study, highlighting the most effective and specific means to overcome the existing barriers. We have also explored the effect of several firm characteristics, such as firm size and energy intensity offering suggestions for industrial decision-makers as well as policy-makers.

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most promising mechanisms to increase SMEs' energy efficiency.

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In literature, too little research has dealt with the identification, characterization and empirical investigation about the most promising means on which making leverage to overcome such barriers, i.e. drivers. Indeed, at the moment, we have a few contributions trying to model and describe them in detail, limiting quite often to their simple identification (De Groot 2001; Del Rio Gonzalez 2005; Thollander and Ottosson 2008; Thollander and Dotzauer 2010). Moreover, scholars have done too little efforts in providing empirical evidence about drivers, as first contributions can be found, e.g. in Sweden (Rohdin and Thollander 2006; Rohdin et al. 2007), Italy (Cagno and Trianni 2013) and Germany (Schleich 2004; Jochem and Gruber 2007). For a recent summary of empirical studies focused on drivers, see Brunke et al. (2014).

AQ5

Nevertheless, to be most effective from a methodological perspective, drivers should be modelled in order to precisely understand which are the major stakeholders able to promote them within the decision-making process of adopting EEMs (Hasanbeigi et al. 2010). Hence, specific attention should be paid in understanding the role of major stakeholders (e.g. financial institutions, energy suppliers, industrial associations and groupings, manufacturers, suppliers, installers, ESCOs) of the so-called energy efficiency supply chain (Hirst and Brown 1990; Vidil and Marvillet 2005; Liu et al. 2012; Abdelaziz et al. 2011). Taking inspiration by Reddy et al. (2013) and Trianni et al. (2013c), Trianni et al. (2016a) have recently developed an innovative classification and categorization of drivers for industrial energy efficiency. According to the authors, drivers are defined as 'factors promoted by one or more stakeholders, stimulating the sustainable adoption of energy-efficient technologies, practices and services, influencing a portion of the organization and a part of the decision-making process in order to tackle the existing barriers' (Trianni et al. 2016a). Drivers have been also classified into four categories, namely: regulatory (R), economic (E), information-related (I) or related to vocational training (VT), as reported in Table 1. Additionally, the study discusses whether a driver arises internally or externally, with respect to a firm. Such a feature is relevant as it clearly points out which drivers should be

promoted by external stakeholders with respect to those that should arise internally for stimulating the adoption of EEMs. The authors have also attempted to model the mechanisms relating barriers and drivers in the decision-making process, identifying a possible set of relevant stakeholders able to tackle the existing barriers. The framework describing the mechanisms relating drivers on barriers within the decision-making process is quite complex, as reported in Fig. 1. In particular, Trianni et al. (2016a) have structured the decision-making process in six steps, as follows: (i) awareness; (ii) needs and opportunity identification; (iii) technology identification; (iv) planning; (v) sustainability analysis; and (vi) installation, start-up and training. In particular, mechanisms should be intended as the effect of drivers on barriers in a specific decision-making step. Such mechanisms could be different along the decision-making process, i.e. the same driver could affect the same barrier with different strength in two separate steps; a driver could tackle multiple barriers in a specific step with different strength; and more drivers could affect the same barrier in a specific step. As a consequence, the picture—using different lines (bold, continuous, dotted)—aims at pointing out that a driver may have a different strength in tackling different barriers within the decision-making process.

Table 1

A novel taxonomy of drivers for energy efficiency (source: Trianni et al. 2016a)

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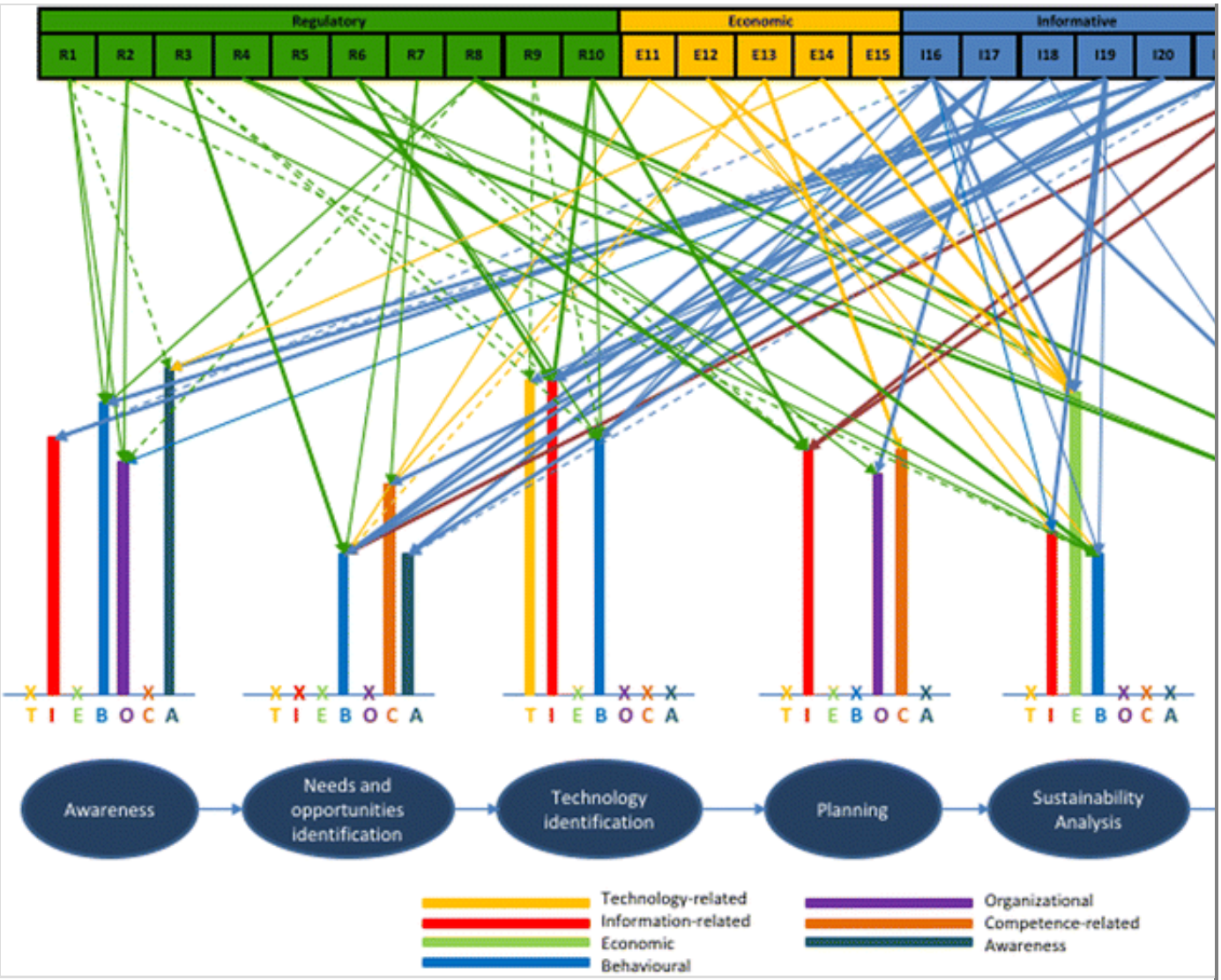
Categories	ID	Drivers
Regulatory internal	R1	Green image
	R2	Long-term energy strategy
	R3	Voluntary agreements
	R4	Willingness to compete
Regulatory external	R5	Clarity of information
	R6	Efficiency due to legal restrictions
	R7	External energy audit/submetering
	R8	Increasing energy tariffs
	R9	Technological appeal
	R10	Trustworthiness of information
Economic internal	E11	Cost reduction from lower energy use
	E12	Information about real costs

Economic external	E13	Management support
	E14	Public investment subsidies
	E15	Private financing
Informative internal	I16	Knowledge of non-energy benefits
	I17	Management with ambitions
	I18	Staff with real ambitions
Informative external	I19	Availability of information
	I20	Awareness
	I21	External cooperation
Vocational training internal	V22	Programs of education and training
Vocational training external	V23	Technical support

Fig. 1

The framework describing the relationships between drivers and barriers in the decision-making process (for the correspondence between drivers and codes reported, please refer to Table 1) (source: Trianni et al. 2016a)



By adopting the novel approach proposed by Trianni et al. (2016a), the present study aims at empirically investigating drivers in SMEs. Taking inspiration from Brunke et al. (2014), we have conducted our study investigating simultaneously barriers and drivers for industrial energy efficiency. Nevertheless, with respect to previous contributions (see, e.g. Trianni et al. 2016b), instead of just looking at major barriers and drivers in general terms, the investigation has detailed and analysed the major mechanisms relating drivers to barriers in the decision-making process, being apparent that both can vary their strength over the decision-making process (as can be inferred from Fig. 1). Finally, thanks to an accurate company profiling, we have preliminarily explored the role of some firm's characteristics, such as energy intensity and firm size (within SMEs), in order to appreciate commonalities and differences. The remainder of the paper is organized as follows: Section 2 is devoted to describing the research methods, and Section 3 presents and discusses the results. Concluding remarks and further research are reported in Section 4.

Research methods

Our empirical research takes on the multiple-case study methodology based on Yin (2003), considering the exploratory nature and the complexity of elements under investigation. The three conditions proposed by Yin (2003) are met since (1) the nature of the research questions is indeed explanatory, (2) the extent of control over behaviours is very low (ultimately absent) and (3) the focus is exclusively on contemporary events. Furthermore, by the definition of multiple-case study, the research intentionally intends to cover not only 'the' contextual settings but also 'across' these settings in which the perceptions of drivers and of barriers are going to be investigated, giving evidence considered more robust and reliable, although the contexts of cases are likely to differ to some extent. As Yin (2003) pointed out and Baxter and Jack (2008) detailed, a fundamental step regards the formulation of the research questions, in particular:

- What are the main drivers acting on barriers within a firm decision-making process of adopting EEMs?
- Do some firm characteristics, such as energy intensity and firm size (within SMEs), influence the results from the previous question and how?

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Case selection procedure

With regard to the unit of analysis, we have carried out our investigation within single companies in a cluster of manufacturing SMEs located in the Lombardy region (Northern Italy). In particular, we decided to deal with medium-sized firms as, compared to smaller ones, they usually present a more structured organization and a more defined decision-making process. Therefore, for the purposes of the study, we are able to better highlight and analyse the issues, still falling within the world of SMEs' general problems and relevance (Cagno et al. 2010).

Regarding the context of the investigation, we have chosen to investigate enterprises located in Lombardy region (Northern Italy). The region is of great interest since it produces more than 20 % of the national gross domestic product (Eurostat 2015) and represents the richest, most developed and most industrialized Italian region, with a GDP per capita 29 and 37 % higher than the national one and the EU-25 one, respectively (Lombardy Region 2016). Moreover, the number of manufacturing enterprises operating in the region is

quite large (around 800,000), with a vast majority of firms (99.6 %) being classified as SMEs, 17.9 % of which being classified as medium enterprises (MEs). Referring to the International Standard Industrial Classification of all Economic Activities (ISIC) (ATECO 2007), the focus of Lombardy's industry is on manufacture of non-metallic mineral products (C23), manufacture of basic metals (C24), manufacture of fabricated metal products (C25) and manufacture of machinery and equipment (C28).

For the exploratory purpose of the investigation, we have contacted 430 enterprises identified via a database containing relevant industrial information (AIDA 2013). The final selection, according to their interest to participate to the research, was made by contacting the enterprises via phone, to check their availability for the interview. Sixty-one cases were selected. Given that the current research builds on the approached proposed by Trianni et al. (2016a) in an exploratory manner and given that, according to case study research methods, the study is judged on its theoretical generalisability—rather than its statistical one (Eisenhardt and Graebner 2007)—the sample size was deemed to be sufficient. Therefore, we have conducted 61 phone interviews to obtain data and to make quantitative as well as qualitative evaluations. We have decided to conduct phone interviews as they present the following advantages: it is possible to achieve higher response rates; interviewers are able to document characteristics of non-respondents and reasons for refusal; the amount of non-response to questionnaire items can be minimized; and we are able to obtain results quickly (THCU 1999).

The investigated sample is structured as follows. The sampled enterprises belong to the most relevant sectors for the Lombardy region, including metalworking companies, non-metallic minerals, textiles, plastics, food and wood manufacturing. Such dispersed distribution of the sample does not allow us to perform a cluster by sector. For that reason, companies have been clustered according to the energy intensity, calculated as the ratio between energy expenditures and net turnover, following previous research (Rohdin and Thollander 2006). In particular, 20 enterprises have been classified as energy intensive (EIs) (i.e. with a ratio greater than 2 %), whilst 41 as non-energy intensive (NEIs). Moreover, the sample has been divided into two clusters according to firm size: medium-small enterprises (MSEs)—with a number of employees between 50 and 99—and medium-large enterprises (MLEs)—with a number of employees between 100 and 250. In fact, previous studies dealing with organizational process and SMEs highlighted a possible different

behaviour of MSEs with respect to MLEs (for energy efficiency issues, see, e.g. Trianni and Cagno 2012; for occupational health and safety management, see, e.g. Micheli and Cagno 2010; Masi and Cagno 2015). The AIDA (2013) database has been also used to report secondary data from enterprises, which have been verified, updated and complemented during the interviews.

Data collection and analysis

Semi-structured interviews were conducted with the person in charge of energy efficiency investments. The interview was led by two experts, so to limit as much as possible the interviewers' bias. Regarding interviewees, when contacting enterprises, we have specifically required that the interviewee had thorough technical knowledge of the production processes and energy issues, as well as being strongly involved within the company board. The large majority of interviewees were in the position of plant manager. Nevertheless, in a very few cases, we had the opportunity to discuss with energy managers (but too few for clustering companies according to this feature). During the phone interviews, additional information about the company as well as its energy efficiency issues was gathered (including but not limited to, e.g. annual energy expenditures, general description of the production process, major energy consuming appliances in the plant, number of EEMs implemented in the recent past), allowing to enhance the results' quality and providing further background for the discussion. Questions were asked to the different interviewees in exactly the same way, within a relatively short time frame, so to limit as much as possible respondent's bias.

The interview has been divided in two parts, for a total duration of about 1 h. In a preliminary introduction (before the interview itself), we have devoted some extra time to the presentation of the investigation, as well as to a short description of the research framework. We have also described drivers and barriers in detail although, for time limitation, we have limited the investigation of barriers by category—taking benefit from the taxonomy developed by Cagno et al. 2013 (Table 2) and used for the research framework by Trianni et al. (2016a). The categories of barriers are as follows: economic, behavioural, lack of awareness, competence-related, information, organization and technology-related barriers. Regarding drivers, we followed the approach proposed by Trianni et al. (2016a) (Fig. 1). Hence, 23 drivers have been investigated, whereas a six-step decision-making process has been adopted.

Table 2

Taxonomy of barriers adopted in the present study

Categories	Barriers
Technology-related	Technologies not adequate
	Technologies not available
Information-related	Lack of information on costs and benefits
	Information not clear by technology providers
	Trustworthiness of the information source
	Information issues on energy contracts
Economic	Low capital availability
	Investment costs
	External risks
	Intervention not sufficiently profitable
	Intervention-related risks
	Hidden costs
Behavioural	Other priorities
	Lack of sharing the objectives
	Lack of interest in energy efficiency interventions
	Imperfect evaluation criteria
	Inertia
Organizational	Lack of time
	Divergent interests
	Lack of internal control
	Complex decision chain
	Low status of energy efficiency
Competence-related	Implementing the interventions
	Identifying the inefficiencies
	Identifying the opportunities
	Difficulty in gathering external skills
Awareness	Lack of awareness

Detail of barriers and categories (source: Cagno et al. 2013)

n the first stage, the interviewee was asked to describe the company, the context in which the company operates (sector, markets, etc.), as well as provide his/her view on barriers and drivers to adopt EEMs. At this stage, the seven barriers (by category) and 23 drivers have been asked exclusively in general terms, therefore not related to the six steps of the decision-making process (Fig. 1). In the second stage, the interviewee was asked to point out the most relevant barriers at each decision-making step, indicating and evaluating the most relevant drivers able to tackle them. Due to the large heterogeneity of technologies and processes in place in the sample, we refrained from asking technology-specific questions nor evaluating barriers and drivers with respect to specific EEMs (Cagno and Trianni 2014).

Interviews have been recorded and transcribed for complementing judgments with the additional comments gathered. Once responses have been separately evaluated by the interviewers based upon their experience, a single value for each response has been calculated. Drivers and barriers have been evaluated on an even Likert scale ranging from 1 (not relevant), 2 (slightly relevant), 3 (relevant), up to 4 (very relevant). Indeed, we have adopted a 4-point even scale because it was possible to classify the responses with an additional cutoff criterion between low and high relevance of drivers and barriers. The processed information has been classified in a database for single case as well as cross-case analysis.

Results and discussion

The present section reports the results of the exploratory cases. In particular, Section 3.1 is focused on the analysis of the whole investigated sample, with a separate focus on barriers, drivers and effect of drivers on barriers through the decision-making process. Section 3.2 reports a preliminary analysis by clusters of enterprises, looking at differences—with respect to the whole sample—according to firm size and energy intensity. Considering the exploratory nature of the study and limited sample size, responses about barriers and drivers were put on a simple average, as a first approximation. This operation has been performed both for the whole sample and for each cluster. Findings have been compared without any statistical test of significance, due to the limited sample. For the same reason, only major pieces of evidence have been discussed.

Analysis of the whole sample

Barriers

In Fig. 2, we have ranked the barriers according to their average scores. Economic barriers constitute by far the largest barriers to energy efficiency, confirming the vast majority of previous literature (see, e.g. Brunke et al. 2014 and Catarino et al. 2015). In second place, we can find behavioural barriers, such as other priorities and lack of interest in energy efficiency issues. This aspect is further supported by the fact that in the third position we find the barrier lack of awareness, with an average score of 2.57, leading enterprises to neglect energy efficiency issues. Given the nature of the sample explored, it seems reasonable that organizational barriers are classified in a lower position (average score of 2.30). In fact, our interviewees did not point out specific organizational issues as long decision chains (Trianni and Cagno 2012; Sorrell et al. 2010). Moreover, with the interviewees being (in many cases) in the position of plant manager, thus in charge of many activities and responsibilities including the coordination between different units, they might be reluctant to highlight their own difficulties, as previous research shows (Trianni et al. 2013b). Finally, information and technology-related barriers emerge as low. In fact, a large portion of firms claimed to have the knowledge about the available technologies on the market, receiving an adequate and a satisfactory amount of information.

Fig. 2

Barriers to industrial energy efficiency – average values – whole sample

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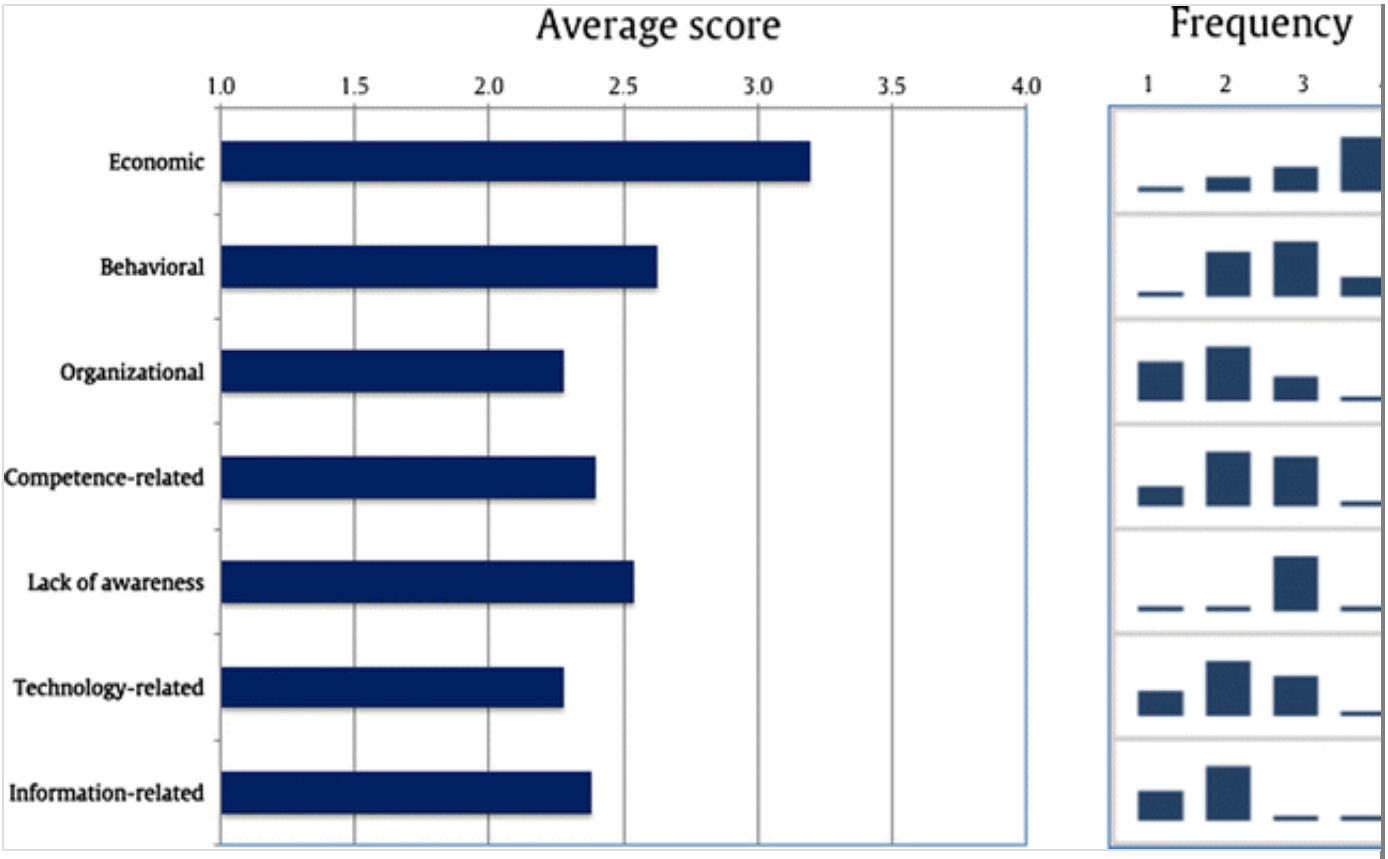


AQ8

From Fig. 2, we can see that, despite having the same average, two barriers may present a different distribution of frequencies. In particular, we can notice this difference between behavioural barriers and awareness. Furthermore, to explore some major linkages in the barriers, we have calculated the correlation coefficient between the responses. Among them, here we can note some correlations (value equal to 0.62) between technology-related and information ones (see Table 3). The finding might reflect that knowledge of new EEMs available on the market could be hindered by issues related to the information availability. Nevertheless, it should be remarked here that both barriers emerged here as of minor importance.

	Economic	Behavioral	Organizational	Competence-related
Economic	-			
Behavioral	0.25	-		
Organizational	0.12	0.04	-	
Competence-related	0.04	0.19	0.24	-
Lack of awareness	0.04	0.06	0.08	0.22
Technology-related	0.19	0.27	0.25	0.43
Information-related	0.22	0.21	0.04	0.32

Table 3

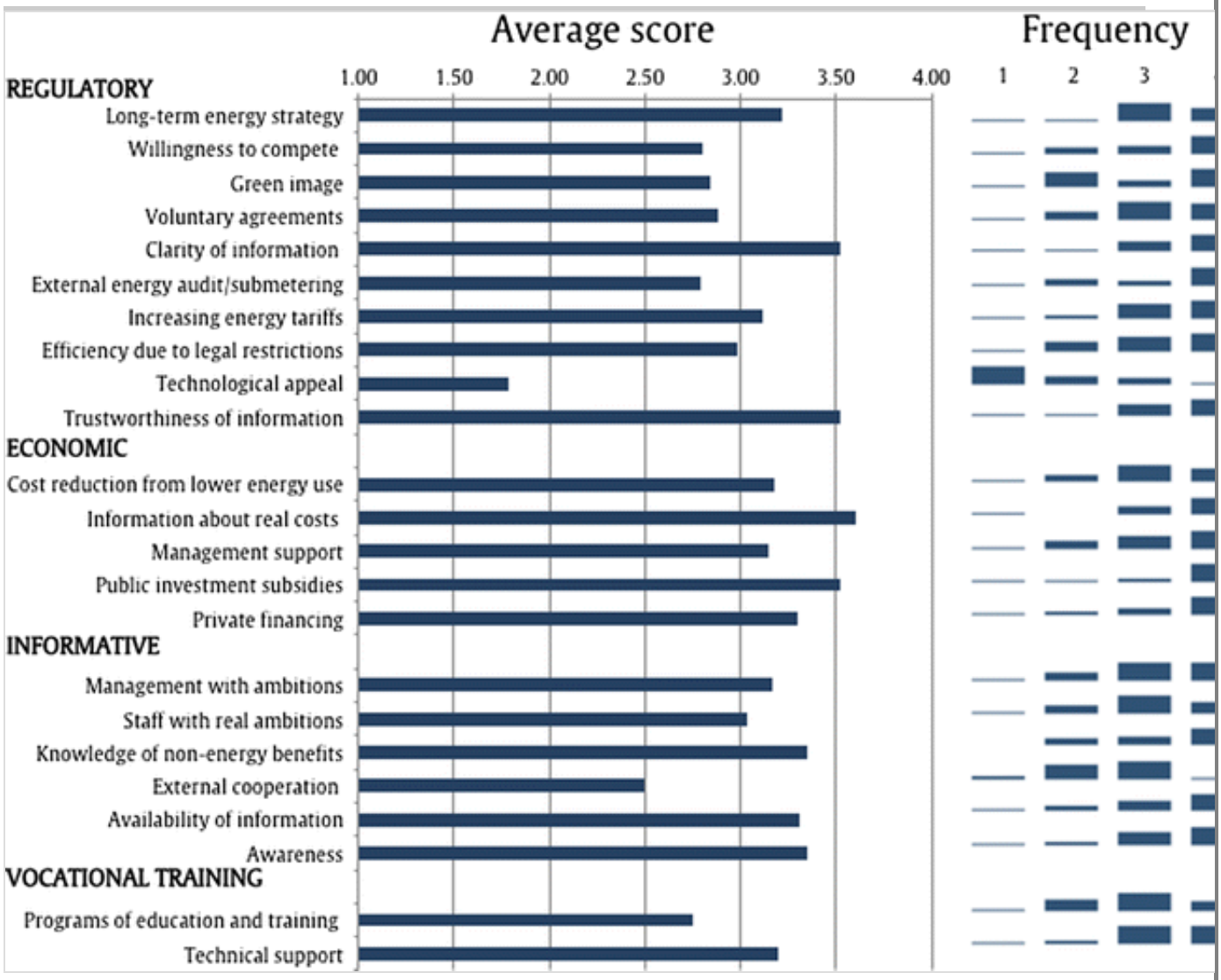
Barriers to industrial energy efficiency – correlation matrix – whole sample

Drivers

Figure 3 ranks drivers according to their simple average score. The four most important drivers—i.e. information about real energy costs, trustworthiness of information, public investment subsidies and clarity of information presenting scores of 3.60, 3.53, 3.52 and 3.52, respectively—seem to reveal different aspects perceived as very important by interviewees.

Fig. 3

Drivers to industrial energy efficiency – average score – whole sample



Our findings seem to suggest that enterprises recognize the primary relevance of economic drivers, such as information about real energy costs. Indeed, if energy costs would account for all the externalities, energy efficiency would

result in a much more competitive and remunerative option. For this reason, having a precise knowledge of the real energy costs, thus excluding any subsidy, would represent an important driver to adopt EEMs. By looking at previous research, we can find confirmation of our findings regarding economic drivers, as in the studies of de Groot et al. (2001) and Trianni et al. (2013b), especially for what concerns public investment subsidies. Additionally, interviewees have pointed out the need of having trustworthy, clear and available information (average score of 3.53, 3.52 and 3.32, respectively). Indeed, standardizing the set of information offered to companies appears as a strong driver for EEMs adoption, reducing the time by decision-makers to analyse gathered information. Similarly, increased awareness is an informative driver considered to be very important (3.35). Since this driver could be promoted through sensitization campaigns, it is again emphasized the importance of receiving adequate, trustworthy and clear information from external sources. In this regard, it is remarkable the attempt by scholars to offer new platforms for sharing information about suggested and implemented EEMs (Blomqvist and Thollander 2015). Even the driver 'knowledge of non-energy benefits' has been classified as particularly important, i.e. understanding that the adoption of EEMs may result in several benefits in addition to energy savings (Worrell et al. 2003). Indeed, during the discussion, a particular interest by interviewees was given to the knowledge of benefits such as enhanced safety or improved quality, resulting from the implementation of EEMs. In this regard, recent contributions in literature have offered a classification of EEMs, trying to point out their major characteristics and features (Fleiter et al. 2015; Trianni et al. 2014), as well as sketching the positive impacts from the adoption of EEMs at all levels (thus beyond the industrial sector) (IEA 2014). Finally, our interviewees seem to recognize neither external cooperation (2.60) nor technology appeal (1.80) as major drivers, due basically to a distrust in competitors and a very rational approach to technologies, thus more focused on improved production performance than EEMs appeal.

AQ10

By grouping drivers by categories, economic drivers are evaluated as most important (3.35), followed by informative ones (3.11). Regulatory and vocational training drivers present quite similar results (2.95 and 2.98, respectively). Here the relevance of such drivers find a wide confirmation in literature, as found by previous research in Sweden (Thollander and Ottosson 2008) and Lithuania (Streimikiene et al. 2008). Nevertheless, considering here the distinction between internal and external drivers, we can observe an

interesting finding: the investigated sample has not shown great differences between the two categories (with scores in both cases slightly higher than 3). Therefore, it seems to show an equal relevance by both external and internal driving forces to promote the adoption of EEMs. By considering possible stakeholders responsible of drivers' promotion, the picture may look even more interesting. Indeed, despite the existence of external stakeholders (such as financial institutions for, e.g. capital, or technology suppliers for, e.g. clear and reliable information), firms themselves are responsible of many activities to stimulate energy efficiency internally (as, e.g. highlighting the relevance of implementing EEMs for cost reduction, or for an increased knowledge of the benefits from EEMs' adoption).

We have then performed a correlation analysis between drivers (Table 4). We have observed that, in general terms, low correlation coefficients can be found, some interesting exceptions being. Firstly, clarity and trustworthiness of the information are strongly correlated (0.96). With lower correlation coefficients, also information about real energy costs and availability of information are correlated with clarity and trustworthiness of information. Indeed, interviewees highlighted that receiving adequate information about EEMs was deemed to be really crucial, as the clearer the information was perceived, the more trustworthy its source was perceived, thus with stronger potential for an EEM to be adopted. Additionally, management and staff with real ambitions and commitment are strongly correlated (0.89). As pointed out from the interviews, the efforts to improve energy efficiency are of course led by company management. Nevertheless, it surely involves at least part of the staff, especially when dealing with EEMs that require a behavioural change (such as, e.g. 'make a practice of turning off the equipment when not in use'). Additionally, reasonably due to the company size (our investigation has not involved large enterprises), we observed a strong correlation (0.78) between management and technical support. In fact, adopting an EEM could be in some cases a complicated process requiring specific managerial and technical competence, as research has previously shown (Sorrell et al. 2010). Therefore, interviewees may have pointed out that external support would be useful to, e.g. manage the many procedures and the overall project, from the very beginning to the conclusion. Similarly, technical support may be crucial to implement new practices or use new equipment more efficiently. Finally, private financing and public investment subsidies seem to be correlated (0.79), reflecting the need from enterprises to receive external economic support, here expressed through different means (either public or private).

CORRELATION MATRIX - DRIVERS			REGULATORY										ECONOMIC		
			INTERNAL (I)				EXTERNAL (E)						I		
			Green image	Long-term energy strategy	Voluntary agreements	Willingness to compete	Clarity of information	Efficiency due to legal restrictions (reg. and stds)	External energy audits/sub-metering	Increasing energy tariffs	Technological appeal	Trustworthiness of information	Cost reduction from lower energy use	Information about real costs	Management support
REGULATORY	INTERNAL (I)	Green image	-												
		Long-term energy strategy	0.03	-											
		Voluntary agreements	0.36	0.07	-										
		Willingness to compete	0.10	0.22	0.04	-									
	EXTERNAL (E)	Clarity of information	0.13	0.09	0.12	0.13	-								
		Efficiency due to legal restrictions (reg. and stds)	0.30	0.29	0.34	0.05	0.33	-							
		External energy audits/sub-metering	0.35	0.00	0.20	0.06	0.04	0.04	-						
		Increasing energy tariffs	0.13	0.21	0.22	0.05	0.04	0.33	0.08	-					
		Technological appeal	0.17	0.34	0.24	0.04	0.05	0.04	0.22	0.14	-				
		Trustworthiness of information	0.09	0.06	0.12	0.06	0.06	0.05	0.28	0.04	0.08	-			
ECONOMIC	INTERNAL (I)	Cost reduction from lower energy use	0.03	0.02	0.02	0.16	0.38	**0.96**	0.03	0.24	0.06	0.46	-		
		Information about real costs	0.16	0.07	0.09	0.14	0.77	0.38	0.27	0.04	0.03	**0.76**	0.35	-	
	EXTERNAL (E)	Management support	0.31	0.05	0.20	0.13	0.38	**0.77**	0.63	0.09	0.18	0.39	0.10	0.30	-
		Public investment subsidies	0.16	0.07	0.51	0.19	0.09	0.28	0.17	0.06	0.02	0.12	0.02	0.06	0.09
		Private financing	0.24	0.08	0.45	0.13	0.12	0.09	0.27	0.05	0.03	0.07	0.16	0.11	0.10
INFORMATIVE	INTERNAL (I)	Knowledge of non-energy benefits	0.42	0.04	0.37	0.15	0.01	0.12	0.40	0.16	0.33	0.24	0.01	0.07	0.32
		Management with real ambition/commit.	0.03	0.18	0.06	0.24	0.07	0.29	0.14	0.04	0.02	0.02	0.02	0.19	0.01
		Staff with real ambitions	0.01	0.15	0.08	0.16	0.29	0.01	0.14	0.02	0.03	0.04	0.01	0.30	0.03
	EXTERNAL (E)	Availability of information	0.10	0.13	0.37	0.13	0.22	0.07	0.29	0.10	0.13	**0.78**	0.26	0.17	0.37
		Awareness	0.19	0.04	0.13	0.05	0.70	**0.70**	0.27	0.03	0.01	0.08	0.17	0.55	0.23
		External cooperation	0.29	0.15	0.35	0.01	0.03	0.03	0.39	0.12	0.37	0.25	0.17	0.01	0.37
VOC. TRAIN		Programs of education and training	0.07	0.12	0.08	0.20	0.13	0.22	0.36	0.06	0.18	0.14	0.24	0.05	0.31
	EXTERNAL (E)	Technical support	0.27	0.04	0.10	0.14	0.49	0.13	0.58	0.23	0.07	0.48	0.30	0.42	**0.78**

Table 4

Drivers for industrial energy efficiency – correlation matrix – whole sample

Analysis of drivers on barriers within the decision-making process

In the following, we have analysed each step of the decision-making process, highlighting the major mechanisms between drivers as barriers in each step, as synthesized in Table 5. As major mechanisms, we have here reported exclusively those relationships when pointed out by at least one fourth of the interviewees.

Step 1: *Awareness.* Awareness and behavioural barriers have been widely considered as primarily important at this stage. Long-term energy strategy and clarity of information are deemed as effective drivers to increase the awareness, while voluntary agreements as useful instruments to tackle behavioural issues. Indeed, the presence of a long-term energy strategy, thus setting targets, objectives, etc. is able to increase the interest towards energy efficiency. A similar effect may be obtained setting specific standards for conveying clearer information to companies.

Step 2: *Needs and opportunities identification.* The specific identification of needs, as well as where energy efficiency opportunities may be found, are mainly hindered by information-related and organizational barriers. Indeed, available, clear and trustworthy information are recognized as most effective drivers to tackle information-related barriers. This emerged as quite critical, as companies at this stage declared to disregard vague and partial information about energy efficiency opportunities. Additionally, according to our interviewees, management with real ambitions as well as external technical support are major drivers in tackling organizational issues, mainly by devoting proper time to the research of energy efficiency opportunities and increasing the priority of energy efficiency issues.

Step 3: *Technology identification.* Information-related and technology-related barriers hinder the identification of specific EEMs, mainly tackled by the following drivers: availability, clarity and trustworthiness of information. In fact, only through a precise identification of an EEM it is possible to precisely define its costs and benefits (information barrier), as well as its effective suitability for the case (technology-related barrier). This emerged quite clearly from our interviews, as interviewees claimed to stop the decision-making process when the availability and suitability of the identified measure were somehow perceived as unclear. External stakeholders, through proper technical support, may offer here a relevant contribution here.

Step 4: *Planning.* Our sample highlighted here a major relevance of organizational issues. In particular, management with real ambition (internal driver), as well as technical support offered by external stakeholders, may lead to a simplified decision chain regarding how and when implementing an EEM. Additionally, long-term energy strategy here helps reduce the intervention-related risks and the hidden costs due to, e.g. production disruption.

Step 5: *Sustainability analysis.* The whole investigated sample highlighted the major relevance of economic barriers at this step. Interestingly, both regulatory and economic, internal and external drivers have been pointed out to tackle such barriers. Indeed, long-term energy strategy, as well as voluntary agreements (regulatory internal), are deemed to tackle the low capital availability, as also done by public investment subsidies

(economic external). Additionally, increasing energy tariffs (regulatory external), as well as cost reduction from lowered energy use and information about real energy costs are able to increase EEMs' profitability.

Step 6: *Installation start-up and training.* Behavioural barriers emerged here as most critical. Staff with real ambition as well as technical support are recognized here as valuable drives. Regarding the first, tracking the adopted measures would be helpful to, e.g. standardize complex procedures addressed for the first time by staff and evaluate the actions just undertaken. For what concerns the latter, external stakeholders, such as policy-makers, technology suppliers, installers, etc. could, e.g. promote training courses for managing new equipment as well as for implementing energy-efficient practices within plant's operations.

Table 5

Main mechanisms (decision-making step–barriers–drivers) identified by firms

D-M step	Main barriers	Main drivers	Category
1st	Awareness and behavioural	Long-term energy strategy	Regulatory internal
		Clarity of information	Regulatory external
		Voluntary agreements	Regulatory internal
2nd	Information-related and organizational	Clarity of information	Regulatory external
		Trustworthiness of information	Regulatory external
		Availability of information	Informative internal
		Management with real ambition	Informative internal
		Technical support	Vocational training external
	Information- and	Trustworthiness of information	Regulatory external
		Availability of information	Informative internal

3rd	technology-related		
		Clarity of information	Regulatory external
		Technical support	Vocational training external
4th	Organizational	Technical support	Vocational training external
		Management with real ambition	Informative internal
		Long-term energy strategy	Regulatory internal
5th	Economic	Public investment subsidies	Economic external
		Cost reduction from lower energy	Economic internal
		Long-term energy strategy	Regulatory internal
		Increasing energy tariffs	Regulatory external
		Information about real costs	Economic internal
		Voluntary agreements	Regulatory internal
6th	Behavioural	Staff with real ambition	Informative internal
		Technical support	Vocational training external

To summarize, our preliminary findings stemming from this exploratory study seem to suggest that in the first step the most relevant drivers are regulatory ones (both internal and external), whilst in the second and especially third decision-making step, the lion's share is played by external drivers (economic ones excluded). The relevance of internal drivers is instead more pronounced when considering the fourth and fifth step. In particular, in the latter, the strength of economic drivers seems to be even more evident.

Analysis of the clusters

Due to the limited number of responses, in the following, we will present and discuss only the major pieces of evidence emerged by clustering enterprises

according to their energy intensity and firm size.

For what concerns barriers (Fig. 4), interestingly, a difference (half point over 4) can be observed between awareness barriers within NEIs and EI enterprises (with scores of 2.73 and 2.23, respectively). Indeed, for NEIs, awareness represents the second major barrier, after economic issues. Some differences can also be appreciated regarding firm size: indeed, economic barriers result to be particularly high for MSEs (average score of 3.47), more than half a point over MLEs (2.94). The results are aligned with previous literature (e.g. Trianni et al. 2013a, b, c), for which smaller industrial users show larger economic barriers. Finally, awareness barrier presents a remarkable difference, being higher for MSEs (2.75, compared to 2.38 for MLEs). Although it is not possible to draw further conclusions due to the limited sample size, the results seem to show that non-energy intensive smaller enterprises present larger awareness barriers and thus should be carefully considered by policy-makers and industrial stakeholders.

Fig. 4

Barriers to industrial energy efficiency — analysis by clusters of enterprises

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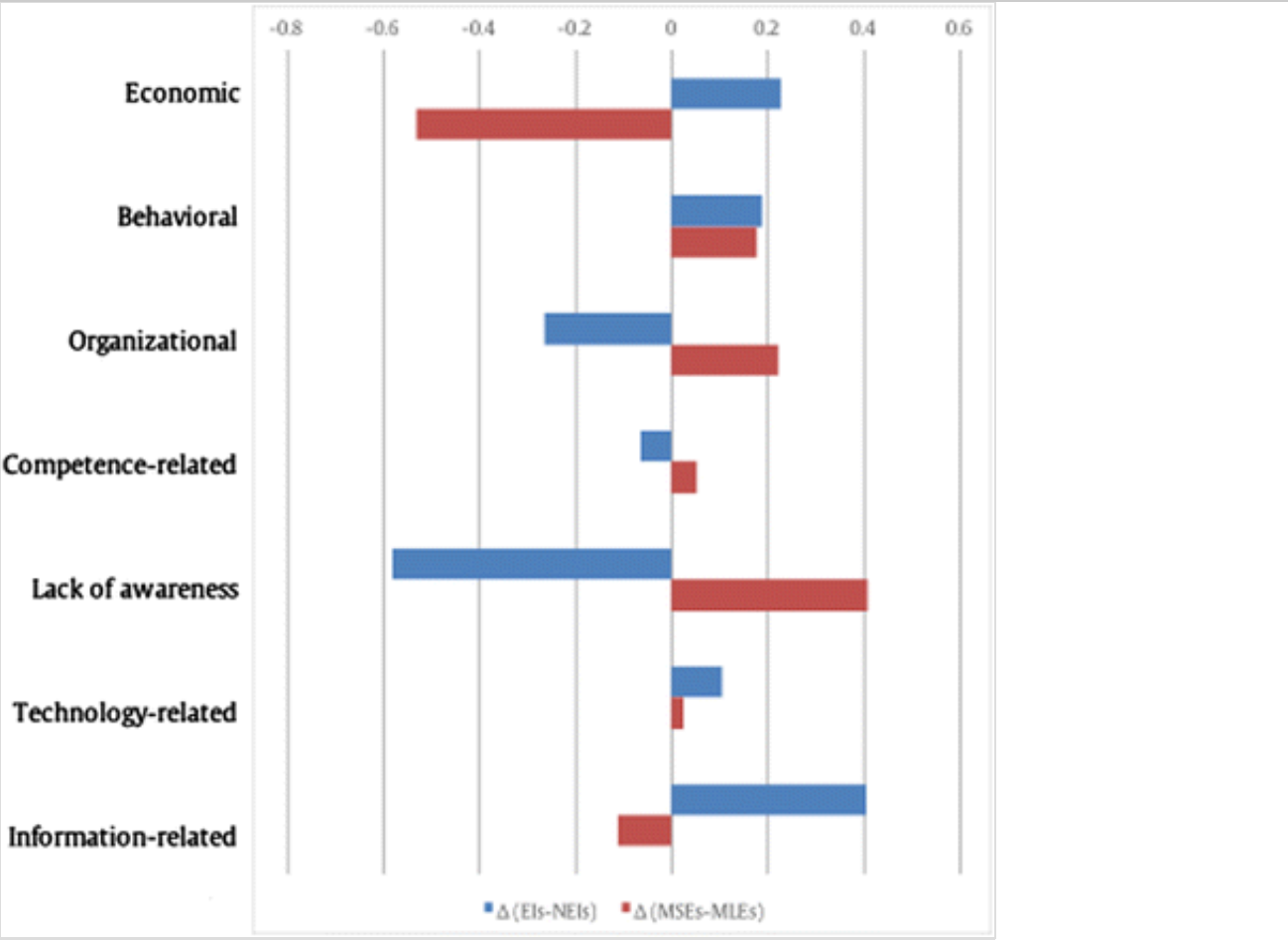
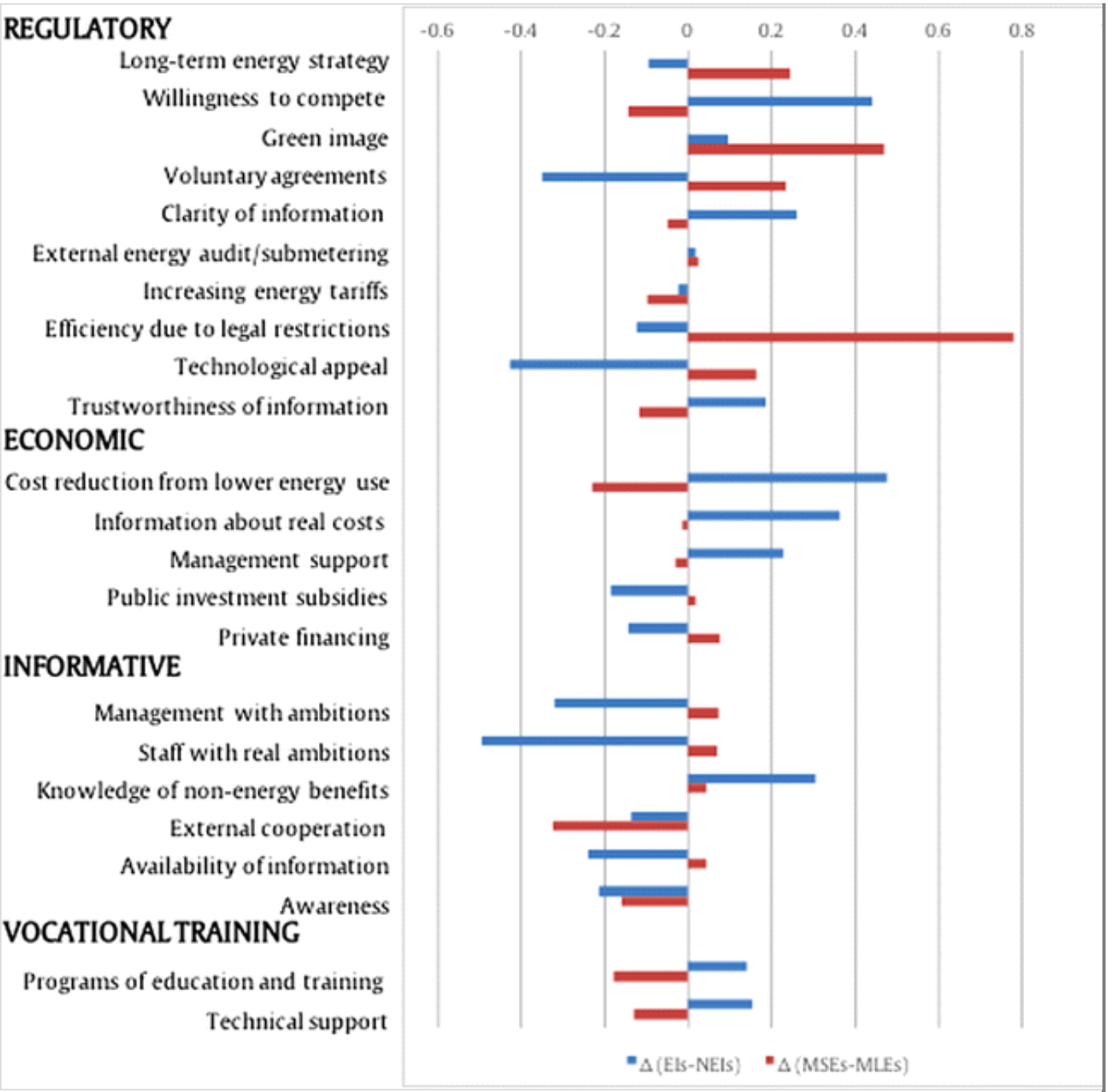


When looking at drivers (Fig. 5), higher energy intensity seems to be related to larger differences in cost reduction from lowered energy use, staff with real ambition and technological appeal. In fact, cost reduction from lowered energy use (score of 3.61) is considered as very important by a business in which energy expenditures represent a relevant share of the total production costs and turnover (De Groot et al. 2001; Thollander and Ottosson 2008; Hasanbeigi et al. 2010). Additionally, staff with real ambition seems to play a greater role for NEIs (score of 3.20, compared to 2.70 for EI). Reasonably, EI enterprises may present a greater commitment towards energy efficiency issues. Still referring to EIs, Rohdin et al. (2007) consider it as the second most important driver, but the relevance of people with real ambition within the organization has been recognized also in NEIs by previous authors (Rohdin and Thollander 2006). Although not felt as a particularly relevant driver, our investigation has then showed a major relevance of technological appeal for NEIs (score of 1.93, compared to 1.54 for EIs). Here, it should be noted that EIs usually have much more specific technologies than NEIs, thus basing the EEM adoption almost exclusively on their features. Hence, this may lead to totally disregard EEMs' technological appeal. Lastly, EIs have considered willingness to compete as a relevant driver for energy efficiency (3.04 on average, with respect to 2.66 for NEI companies).

Fig. 5

Drivers for industrial energy efficiency — analysis by clusters of enterprises



By analysing drivers clustered by size, interesting differences emerge in some cases. Indeed, for MLEs, the compliance with legal restrictions is deemed as a major driver for EEMs (with an average score of 3.41, compared to 2.60 for MSEs). Similarly, although with a lesser extent, the relevance of the driver green image can be observed (3.03 for MLEs, 2.61 for MSEs), finding a preliminary confirmation in Hasanbeigi et al. (2010). Both results are quite interesting considering the usually different social visibility of the MLEs with respect to MSEs. In fact, both drivers (the first external, the second internal) represent relevant regulatory drivers on which larger companies may make a leverage on for the adoption of EEMs.

Concluding remarks and further research

The academic and industrial debate on energy efficiency issues, on EEMs, as well as on barriers and drivers has become really strong over the last years. The present study has offered a contribution in the discussion providing empirical evidence on the need, for a clearer and more defined comprehension, of a simultaneous analysis of drivers and barriers in the decision-making process of adopting an EEM.

In particular, a preliminary comprehension of the mechanisms relating drivers and barriers in the decision-making process brings additional value to the analysis, as it seems to represent a unique opportunity for highlighting the most effective and specific means to overcome the existing barriers. Moreover, such enhanced specific knowledge would offer benefits not only to the final users but also to the company supply chains in highlighting the most effective needs from companies.

We showed in our study that economic barriers, followed by behavioural as well as awareness, emerged as critical issues, especially for smaller and non-energy-intensive companies. Information about real energy costs, public investment subsidies, as well as clarity and trustworthiness of information emerged as quite relevant drivers in average terms. Nevertheless, our exploratory findings seem to point out that, through an analysis of the specific mechanism drivers-barriers in the decision-making process, something different could be observed. In fact, awareness and behavioural barriers concentrate their effect in the first steps, whilst economic barriers mainly hinder the sustainability analysis (fifth step). Moreover, other barriers of general minor importance can assume critical strength in specific steps of the decision-making process, therefore being able to stop the overall process. And such, barriers could be tackled by specific drivers that in average terms may result as of minor importance, e.g. considering the planning step, organizational issues emerged as most critical, although they were in general deemed as low. Managers with real ambition and technical support were identified as most relevant drivers to tackle such barriers. Additionally, long-term energy strategy is identified as able to reduce the intervention-related risks as well as hidden costs.

It is clear that our findings are exploratory and much additional work should be done. Therefore, future research will be required to widely enlarge and diversify the investigated sample, so to adequately cover the full set of relevant firm characteristics, as well as contextual ones (such as firm size, sector, energy intensity, but also geographical location, presence of an energy manager, etc.)

that may influence the mechanisms, and have just been preliminarily explored in this study. Indeed, enlarging the investigated sample and opening to different research methods such as survey research could indeed represent a valuable opportunity to involve in the research a much broader sample, thus enabling extensive statistical analyses on drivers to energy efficiency as well as the aforementioned elements influencing the relevance of such drivers in specific contexts. In particular, broad sectorial analyses could be quite relevant to support local, regional, domestic or even international policy-makers as well as industrial associations and groupings to understand the needs from specific branches, so to come up with tailored policy instruments supporting companies in improving their energy efficiency.

In this regard, our study has highlighted a relevance of both internal and external drivers, offering several future opportunities for future research. Regarding internal drivers, future work should focus on understanding which are the most effective policies to foster enterprises stimulating internal drivers (e.g. adopting a long-term energy strategy or a voluntary agreement or to have ambitious management and staff). For what concerns external drivers, indeed, it would be quite interesting to better and more specifically understand the role of stakeholders in promoting drivers. Additionally, it seems crucial to analyse how multiple drivers handled by multiple stakeholders may have a different strength on a barrier, in case of several drivers acting on the same barrier. Furthermore, it seems quite interesting to investigate whether mechanisms may vary considering between the adoption of EEMs in general—as done here—with respect to the adoption of specific EEMs. Previous research has started to explore this new perspective, starting from a focus on barriers (Nagesha and Balachandra 2006; Cagno and Trianni 2014).

Finally, future research could also explore multiple perspectives on energy efficiency by considering a much broader set of industrial stakeholders, differently from what done so far (with an almost exclusive focus on end users), so to highlight interesting mismatches that surely may have a negative impact on the energy policies proposed to industrial end users.

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