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Innovation and adoption of energy efficient technologies: An exploratory analysis of Italian primary metal manufacturing SMEs

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HIGHLIGHTS

- Economic and Information emerge as the most relevant barriers to energy efficiency.
- Market, product and process innovation seem relevant factors affecting barriers.
- Firm's size is a factor affecting barriers' perception.

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ABSTRACT

Additional efforts will be needed by European countries to improve the energy efficiency, as with current trends the 20% objective will be missed. Small and medium-sized enterprises (SMEs) manufacturing sector is a promising field, as SMEs are less energy-efficient than larger enterprises. Several studies investigated the barriers to the diffusion of technologies and practices for industrial energy efficiency, but little attention has been paid to understand the factors affecting the perception of such barriers by SMEs. In this multiple case-study, we have investigated 20 Primary Metal manufacturing SMEs in Northern Italy. Economic and information barriers are perceived as the major issues. Interestingly, firm's size, innovativeness of the market in which enterprises operate, as well as product and process innovation are factors affecting barriers to energy efficiency. Differences have been observed within SMEs, especially for information and competence-related barriers. In particular, a more innovative external context in which enterprises operate and a greater production process complexity seem to reduce barriers. Moreover, more product innovative enterprises seem to have a lower perception of behavioral and technology-related barriers. The results of this exploratory investigation provide useful suggestions for policy design and further research on industrial energy efficiency.

1. Introduction

Understanding which barriers limit the adoption of energy-efficient measures (either technologies or practices) within the industrial sector is crucial to develop the most effective policies to overcome such barriers. Recently, the European energy efficiency targets have been revised, as with current trends the target of 20% improvement of energy efficiency will be missed (European Commission, 2011). This is even more critical within SMEs that are considerable energy consumers (e.g., in Italy they cover about 60% of the industrial consumption (ISTAT Istituto Nazionale di Statistica, 2004)), the undisputed lifeblood of European economy (EIM Business & Policy Research, 2011), the drivers for innovation (Porter, 1990), and, at the same time, they are less energy-efficient than larger enterprises (European Commission, 2007).

To be most effective, energy efficiency policies should be shaped according to the factors, e.g. characteristics of the enterprises, and the context in which they operate, that influence the barriers to the adoption of energy-efficient technologies and practices. In fact, literature has shown that some firms characteristics (and, among others, firm size and firm innovativeness) are factors influencing the adoption of environmental innovative technologies (Uhlaner et al., 2011). Nonetheless, studies highlighting which barriers to the adoption of such technologies differ, according to the firm's characteristics, are missing. For this reason, we have conducted a preliminary investigation of Italian SMEs within the primary metals manufacturing sector to study the

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relationship between some firm characteristics, such as firm innovativeness and firm size, and the perception of barriers to energy efficiency improvement.

The paper has been structured as follows: in the next section we review literature of factors affecting the adoption of energy-efficient measures in the industry. Taking reference from a recent taxonomy developed and tested for the investigation of barriers to industrial energy efficiency (Cagno et al., 2013; Trianni et al., 2013b) that constitutes the theoretical backbone of our investigation, in Section 3 we describe the methodological approach used in this study. Section 4 is devoted to the presentation and discussion of results. The final section will propose conclusions and suggestions for further research.

2. Factors affecting the adoption of industrial energy-efficient technologies and practices

A better understanding of the systemic processes by which the adoption of an energy-efficient measure occurs is useful both conceptually and to inform policy-making in support of innovation in more sustainable technologies (Foxon et al., 2005).

The lack of adoption of energy-efficient measures (Anderson and Newell, 2004; Cagno and Trianni, 2012; Chen et al., 2006) has been widely recognized in the literature and coined as the "energy-efficiency gap" (Backlund et al., 2012; Hirst and Brown, 1990). The gap shows the existence of barriers to energy efficiency, which have been thoroughly characterized by several authors (Golove and Eto, 1996; Jaffe and Stavins, 1994; Sorrell et al., 2000, 2004), including the contributions provided by economics – see, e.g. Brown (2001) – , organizational – see, e.g. DeCanio (1998) – and behavioral theories – see, e.g., Stern and Aronson (1984).

Nonetheless, it is clear that the transition to a more sustainable production will require substantially different, i.e. innovative, technologies and practices than those in use today. When considering energy-efficient technologies and energy management practices, they fall under the big umbrella of *eco-innovations*, defined by Beise and Rennings (2003) as "new or modified processes, techniques, practices, systems, and products to avoid or reduce environmental harms". More generally, according to Schumpeter's view, innovation is defined as the setting up of a new production function (Schumpeter 1939, 1947, in McDaniel (2000)), including five specific cases: (1) the introduction of a new good, (2) the introduction of new method of production, (3) the opening of a new market, (4) the conquest of a new source of supply of new materials, and (5) the carrying out of a new organization of any industry (Schumpeter, 1936, in McDaniel (2000)). Innovation literature has widely discussed types of innovations: the basic distinction is between product and process innovations, as well as incremental and radical innovations—see, e.g., Beerepoot and Beerepoot (2007); Feldman (2000); Vidil and Marvillet (2005). Some authors have also provided elements to characterize radical innovations – see e.g., Dahlin and Behrens (2005) – although the majority of innovations are incremental, characterized by being continuous, with minimal improvement in benefits to customers (Herrmann and Wagner, 2006. For what concerns the measures of innovations, we should distinguish between direct and indirect indicators (Becheikh et al., 2006). Other studies have discussed, in terms of benefits and drawbacks, both indirect indicators (such as research and development activities, and patent data. For literature here, see., e.g., Flor and Oltra (2004), Kleinknecht et al. (2002), Acs et al. (2002) and new more direct indicators (innovation count and firm-based surveys: see, e.g., Amara et al. (2004))).

Specifically for energy-efficient technologies and practices, it is noteworthy, with respect to the aforementioned definition by Beise and Rennings (2003), the addition provided by Halila and Rundquist (2011), who point out that eco-innovations may be developed with or without the explicit aim to reduce environmental harm. Indeed, they may also be motivated by the usual business goals such as reducing costs or enhancing product quality. For energy-efficient technologies, pieces of evidence of the so-called *productivity benefits* can be found, e.g., in Worrell et al. (2003), Pye and Mckane (2000), Skumatz and Gardner (2005), Mills and Rosenfelds (1996).

A recent literature review by Schiederig et al. (2012) reveals that the four notions of sustainable, eco, environmental and green innovation show minor differences in their descriptive precision. Demirel and Kesidou (2011) detailed a model of eco-innovation in line with the OECD framework (OECD, 2009), classifying eco-innovations in end-of-pipe pollution control technologies, integrated cleaner production technologies and environmental R&D. Many of the authors of empirical studies highlighted the characteristics of the enterprises (internal factors) and the context in which they operate (external factors) as relevant for the diffusion of eco-innovations, as defined by Kemp and Volpi (2008). Considering external factors, e.g. Hellström (2007) observes that eco-innovation must be supported by a corresponding evolution of social arrangements and institutional support structures. Luiten et al. (2006) and Luiten & Blok (2003) investigate the role of government R&D support to stimulate the development of energy-efficient technologies. Noailly and Batrakova (2010) explore the links between technological innovation and public policies in energy efficiency in buildings. Urpelainen (2011) indicates that export orientation of some countries has large positive effects on energy efficiency innovations with higher electricity costs. Zailani et al. (2012) performed preliminary analyses on the implementation of sustainable supply chain management practices highlighting the role of various actors within the supply chain on the adoption of energy efficiency measures. A recent investigation by Parmigiani et al. (2011) reveals that the nature of stakeholder exposure determines how social/environmental and relational capabilities impact social and environmental outcomes, highlighting the role of the supply chain configuration, or, taking as reference the literature in operations management, the so-called *supply chain complexity* (Bozarth et al., 2009). Other contextual factors are relevant for the adoption of innovative technologies. Hausman (2005) pointed out that a competitive (external) environment positively affects the capability of innovation by small businesses. Indeed, Liu et al. (2012) highlighted that the energy management level of competitors, as well as the internal training on energy saving, stimulates a greater company's involvement level on energy saving activities. Terziovski (2010) analyzed 600 Australian enterprises and revealed considerable differences between SMEs and LEs, in the way innovation culture is diffused within enterprises. Indeed, in SMEs innovation culture does not appear to be neither strategic nor structured. Rather SMEs have informal strategies, largely driven by their CEO, compared to large organizations, that generally have separate strategic-planning units (Hudson et al., 2001). Many studies have reviewed the differences between SMEs and larger enterprises in the adoption of innovative technologies (see, e.g., Porter (1990), Benner and Tushman (2003), Bessant and Tidd (2007), O'Regan et al. (2006), Prakash and Gupta (2008)). This has shown that entrepreneurs and CEOs play the lion's share in the diffusion of innovative technologies within SMEs. Indeed, according to Schumpeter's view of innovation, the cultural innovator is the entrepreneur. Nonetheless, as pointed out by McDaniel (2000), "not all managers or owners of business are entrepreneurs, because one can run a business without trying new ways of *doing* business".