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Energy efficiency determinants: An empirical analysis of Spanish innovative firms

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HIGHLIGHTS

- Drivers of innovation in energy efficiency at firm-level are examined.
- Tangible investments have a greater influence on energy efficiency than R&D.
- Environmental and energy efficiency innovation objectives are complementary.
- Organisational innovation favors energy efficiency innovation.
- Public policies should be implemented to improve firms' energy efficiency.

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ABSTRACT

This paper examines the extent to which innovative Spanish firms pursue improvements in energy efficiency (EE) as an objective of innovation. The increase in energy consumption and its impact on greenhouse gas emissions justifies the greater attention being paid to energy efficiency and especially to industrial EE. The ability of manufacturing companies to innovate and improve their EE has a substantial influence on attaining objectives regarding climate change mitigation. Despite the effort to design more efficient energy policies, the EE determinants in manufacturing firms have been little studied in the empirical literature. From an exhaustive sample of Spanish manufacturing firms and using a logit model, we examine the energy efficiency determinants for those firms that have innovated. To carry out the econometric analysis, we use panel data from the *Community Innovation Survey* for the period 2008–2011. Our empirical results underline the role of size among the characteristics of firms that facilitate energy efficiency innovation. Regarding company behaviour, firms that consider the reduction of environmental impacts to be an important objective of innovation and that have introduced organisational innovations are more likely to innovate with the objective of increasing energy efficiency.

1. Introduction

The increase in energy consumption and its influence on greenhouse gas emissions justifies the greater attention being paid to energy efficiency (EE) and especially to industrial EE. There is a global consensus on the correlation between energy consumption increases and rising greenhouse gas emissions. EE is the most advantageous way to enhance both the security of the energy supply and of decreasing greenhouse gas emissions and other pollution (EC, 2011). It is estimated that around 60% of the reduction of greenhouse gas emissions necessary to achieve the 2020 targets defined by the International Energy Agency (IEA) can be obtained through EE improvements (IEA 2009). The economic literature has also contributed to underlining the role that technological improvements can play in reducing carbon emissions and lowering the cost of this reduction (Jaffe et al., 2004; Popp et al., 2009).

EE improvements at the current level are not enough to ameliorate the effects of increasing worldwide energy demand. However industrial sector reports show that the implementation of existing technology and best practices on a global scale could lead

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to savings of between 18% and 26% of current industrial primary energy consumption (IEA 2008). At the same time, a large number of studies of EE potential indicate that EE cost-effective measures are often not carried out in the industrial sector because of market failures and market barriers, bounded rationality and organisational problems, among other things (Backlund et al., 2012; Brown, 2001; Hirst and Brown, 1990; Jaffe et al., 2004; Linares and Labandeira, 2010; Palm and Thollander, 2010; Trianni and Cagno, 2012).

Energy efficiency in general, and particularly in the industrial sector, is an important way to reduce the threat of global warming, bearing in mind that industry is one of the main energy consumers (IEA, 2013). The European Commission (EC) promotes industrial EE through new energy requirements for industrial capital goods, improvements in the provision of information to SMEs, and measures encouraging the introduction of energy audits and energy management systems (EMS). The EC is also considering efficiency improvements in power and heat generation, ensuring that plans include EE measures throughout all the supply chain (EC, 2011).

The literature is not conclusive with regard to the influence EE has in terms of business performance. Neither does any unique criterion exist on the optimal level of EE (Jaffe and Stavins, 1994). Besides their impact on greenhouse gas emission mitigation, it seems that EE investments are associated with improvements in technological development and innovation in firms. The debate centred exclusively on cost savings derived from EE improvements now turns out to be a very limited approach. For the reasons given above, EE is part of the environmental agenda (Worrell et al., 2009). The contributions from the literature on the impact of eco-innovation and environmental policy on company innovation decisions widen the scope of analytical procedure to more than that exclusively focused on cost savings. Porter and Van der Linde's (1995) article, which introduced a new approach based on the existence of a positive relationship between environmental policies and innovations that enhance product quality, cost savings, and finally company competitiveness, facilitates the study of EE from a new perspective.

One of the challenges facing the study of EE is to identify the characteristics of firms that drive the adoption of EE improvements in order that policy can be correctly designed. This should become an important objective for the Spanish economy, where energy intensity rose 10% between 1990 and 2006 while in the EU15 it fell in the same period (Mendiluce et al., 2010). Although in recent years this trend has apparently improved, basically because of the economic crisis, Spain still leads EU countries in energy intensity (IDEA, 2013). Existing studies corroborate the possibility that the reduction of inequalities in energy intensity between countries could be attributed to the adoption of EE improvements (Greening et al., 1997; Duro et al., 2010). Despite the importance of EE in reaching the economic and environmental sustainability objectives of the *Climate Energy Package*, the results obtained to date are not very encouraging. The large share of final energy consumption taken up by Spanish industry together with the limited incentives provided for companies to adopt process innovations intended to improve EE explain the poor progress registered at macroeconomic level.

This paper examines the characteristics of manufacturing firms associated with energy efficiency innovations in a novel way. Many studies have analysed the role of barriers to the adoption of energy efficiency measures by firms while others have focused on the adoption rate of the energy efficiency measures recommended by energy audits (Fleiter et al., 2012; Sorrell et al., 2011; Trianni and Cagno, 2012). In this paper we analyse energy efficiency from the perspective of innovation objectives. In general, empirical research on innovation at the firm level has yet to incorporate the role of objectives (Leiponen and Helfat, 2010). In our analysis, we specifically examine energy efficiency technological innovation departing from information about the motives and objectives that firms have for innovating. While many papers have analysed eco-innovations in general, we focus on energy efficiency innovation where both competitive and environmental objectives play a significant role, which deserves specific attention.

In order to carry out this analysis, we use an exhaustive sample of innovative firms from the Technological Innovation Panel (PITEC), which offers access to a broad sample of Spanish innovative companies. The paper has two main objectives. First, it goes in depth into the profile of firms that pursue improvements in EE levels among their innovation objectives. Second, the paper analyses whether the behaviour of firms around organisational innovations and the reduction of environmental impact is related to the EE objectives that Spanish manufacturing firms are pursuing. By EE we understand action taken by firms that has the objective of reducing the amount of energy per unit output.

The rest of the paper is organised as follows. The following section briefly reviews the literature and empirical studies. Section 3 describes the data employed in the empirical analysis and the variables used for the estimations. Section 4 illustrates the econometric strategy and presents the results. Section 5 concludes and discusses policy implications.

2. Literature review and empirical studies

There is a broad debate in the economic literature about the benefits of EE. Several contributions state that a large proportion of the industrial sector has not implemented EE improvements despite the fact that they are associated with greater profits rather than costs (Backlund et al., 2012; Brown, 2001; Hirst and Brown, 1990; Palm and Thollander, 2010; Trianni and Cagno, 2012). On the other hand there is a current of thought that argues that EE improvements, far from reducing energy consumption, increase it – 'Jevons' Paradox' – , the so called 'Rebound Effect', that leads to a lowering of prices, at first, and then a subsequent increase that removes the cost savings (Greening et al., 2000; Khazzom, 1980; Sorrell, 2009).

The differences between the EE improvements actually achieved and those considered to be socially optimal have been defined by the literature, from different points of view, as the 'Energy Efficiency Gap' (Jaffe and Stavins, 1994). The most widespread formulation maintains that the 'gap' appears when EE investment is below the socially optimal, in economic and environmental terms (Gillingham et al., 2009). Another reformulation of the same idea considers the 'gap' can be explained as the use of high 'implicit'[2] discount rates to evaluate EE investment decisions, greater than those that are accepted as optimal by the market for other investments with the same risk (Jaffe and Stavins, 1994).

The 'Energy Efficiency Gap' is considered to be the consequence of the existence of numerous market failures, which are understood as deviations from the assumptions of perfect competition, such as barriers associated with economic, organisational and behavioural obstacles and the lack of adoption of organisational innovations in EE management (Backlund et al., 2012).

The debate focuses on the distinction between market failures and market 'barriers'. The economic approach, which is lead by Sutherland (1991) and Jaffe and Stavins (1994), argues that public policy can only try to address market failures like imperfect

[2] The 'implicit' discount rate refers to the expected rate of return required for an investment to be considered cost-effective.