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**Energy Sustainability**

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# WHY DO MANUFACTURING INDUSTRIES INVEST IN ENERGY R&D? *

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ABSTRACT: Energy R&D can have major social and economic impacts and is a critical factor in addressing the challenges presented by climate change mitigation policies. As well as the energy utilities themselves, firms in other sectors also invest in energy R&D; however, while various studies have examined the determinants of R&D in the former, there are no analyses of energy R&D drivers in other industries. This paper seeks to fill this gap by examining the determinants of investment in energy R&D in non-energy industries. We focus on manufacturing industries where we can differentiate between energy and non-energy R&D related expenditure. The empirical analysis is carried out for 21 sectors in Spain for the period 2008–2013. To overcome problems of data availability, we construct a comprehensive database from several surveys. The data show the importance of taking into account the efforts devoted to energy R&D by the manufacturing sectors in order to have more complete information about the total investment made in energy R&D. The results of the estimations indicate the importance of the energy R&D developed by firms that supply the energy utilities.

JEL Codes: Q40, O30, O38

Keywords: Energy R&D, energy demand, energy efficiency, panel data

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## 1. INTRODUCTION

The agreement reached at the Paris Summit to hold the increase in the global average temperature to below 2 ºC poses significant challenges for the energy sector (UNFCCC, 2015). In the case of the European Union, its 2020 and 2030 energy and environmental objectives had already alerted the sector to the need for significant technological change. Indeed, European Commission reports conclude that achieving emission reductions, including the incorporation of renewable energy sources, and improving energy efficiency will only be possible through innovation and technological development in the energy sector (EC, 2010; EC, 2014).

However, perhaps the main challenge facing the energy sector is adapting to climate change policies without compromising security of supply, a challenge that requires new efforts in R&D and innovation (IEA, 2016). Yet, the shortfall in energy R&D is of particular concern when seen in the light of the major technological challenges that face the sector (GEA, 2012; Costa-Campi et al., 2015a; Eurelectric, 2013). The development and integration of renewables to combat climate change and the making of advances in energy storage, carbon capture and storage, smart grids, smart meters and energy efficiency are essential for an energy transition that does not endanger supply security.

Investment in energy R&D is a critical issue in addressing the challenges posed by energy efficiency, the mitigation of climate change and boosting competitiveness (Anadon et al., 2011; OECD, 2011; Eurelectric, 2013; Jamasb and Pollit, 2015). However, while many reports and papers stress that the internal R&D of energy utilities remains low to meet these challenges, utilities are not the only sector investing in energy-related R&D. In fact, many other industries devote a share of their research expenditure to energy issues.

Various papers have recently analysed the R&D determinants of energy utilities firms and the effects of the liberalisation of electricity markets on R&D investment (Costa-Campi et al., 2014; Jamasb and Pollit, 2008; Kim et al., 2012; Salies, 2010; Sanyal and Cohen, 2009; Sterlaccchini, 2012). However, data constraints affecting private R&D expenditure are substantial (GEA, 2012; Jamasb and Pollit, 2015), making it difficult to differentiate between energy and non-energy related R&D in non-energy industries.

Yet, understanding the participation of other sectors in energy R&D and the determinants of this participation is clearly relevant in establishing the overall R&D effort in energy and the impact of energy policy on business decision-making.

Here, we conduct an empirical analysis of 21 manufacturing sectors in Spain for the period 2008–2013. To overcome problems of data availability, we build a comprehensive database drawing on different surveys of innovation in energy-related R&D (Costa-Campi et al., 2017). The analysis of the determinants of R&D investment using industry-level data is frequent in the economics of innovation literature (Cohen, 2010). Although the use of data at this level can give rise to certain limitations if compared to the use of firm-level data, the approach allows us to exploit the advantages of panel data models.

The rest of this article is structured as follows. The following section reviews the literature. The third section presents the model and the variables and describes the data. The fourth section discusses the main results. The last section offers conclusions and presents some policy recommendations.

## 2. BACKGROUND

Energy investment in non-energy sectors is a highly relevant factor to take into consideration when determining the actual amount of energy-related R&D being undertaken. Wiesenthal et al. (2012) estimate the volume of R&D in the energy sector, stressing the important contribution made to it by the sector’s component and equipment suppliers and, hence, the need to include it so as not to underestimate the total amount.

Sanyal and Cohen (2009) report that the producers of energy equipment have conducted most of the R&D and generated most of the innovations made in the energy sector. In a similar vein, Jamasb & Pollitt (2015) point out that energy R&D is as likely to be performed by equipment manufacturers as by the utilities themselves. For this reason, the external acquisition of the R&D of new technologies is an explanatory factor of the technological changes incorporated by energy companies.

Jacquier-Roux and Bourgeois (2002), by analysing patents, demonstrate that much of the research carried out by the energy sector is done by suppliers of equipment and components. They reach this conclusion on the grounds that energy patents owned by suppliers of electrical equipment were more numerous than those owned by the electricity sector. Markard et al. (2004) also emphasise the role played by equipment suppliers in the conducting of R&D for the energy sector. In an empirical study, based on survey data, they find that liberalisation led to significant changes in innovation in the energy sector and show that both utilities and technology manufacturers are investors in energy R&D. Likewise, Salies (2010) shows that it is the suppliers of components and equipment who spend the largest sums on R&D in the energy sector. Finally, Sanyal and Gosh (2013) analyse innovations in the energy sector developed specifically by component suppliers. In a study that examines the effects of the liberalisation of the electricity market on innovation by suppliers of components and equipment, based on an analysis of patents, the authors stress the leading role these suppliers have taken in energy R&D and innovation.

Another branch of the literature stresses that energy companies need to seek collaboration with other entities – public or private – since an organisation cannot solve internally the challenges of research in an efficient manner. Given the market failures and uncertainty associated with the innovative process, both of potentially great impact in the energy sector, it is critical that firms collaborate with other entities and institutions in developing R&D and, so, spread the risks. The innovation literature speaks of a new paradigm, "open innovation", as a means to encourage collaborative innovation (Chesbrough, 2006). Open innovation allows different firms to share the costs and risks of the innovation process, thus strengthening their potential benefits. This approach also acknowledges that knowledge within a company may be insufficient to develop certain kinds of innovation. The concept of open innovation is particularly suited to the energy sector where innovation projects usually require large amounts of capital and face many uncertainties.

Hakim and Heidrick (2008) analyse the role of open innovation in the energy sector and highlight the creation of partnerships between companies from different disciplines (utilities and suppliers of components or machinery) to undertake collaborative R&D in the energy sector field. Cagno et al. (2015), following a survey of 30 companies in the metallurgical sector in Italy, conclude that companies combine internal R&D and open innovation to incorporate lower cost technological improvements in energy efficiency. A significant part of this R&D is performed outside the energy sector in collaboration with other sectors. Finally, Markard et al. (2004) stress the importance of networking for R&D and innovation in an increasingly specialised energy sector.

Other contributions analyse R&D in solar and wind technologies, where the role of equipment and component manufacturers has been instrumental in many developments made to these technological systems. Jacobsson and Bergek (2004) and Neuhoff et al. (2007) demonstrate the growing importance of the innovative work performed by small component suppliers in the technological development of renewable energies. In reporting case studies of developments in the field of renewable energy, the authors highlight the preeminent role played by tech companies outside the energy sector in the development of solar generation (Neuhoff et al., 2007) and wind power (Jacobsson and Bergek, 2004) in Germany. A further report of the close links between the technological development of renewable energy and the role played by suppliers is provided by Nesta et al. (2014).

Together with the important role played by suppliers in developing energy R&D, other factors may also drive R&D investments. For example, energy and environmental policies may encourage non-energy sectors to invest in energy R&D. Firms from non-energy sectors, as well as the suppliers of the utilities industry, may invest in R&D to improve their energy efficiency or to achieve energy self-sufficiency, usually from cogeneration systems. Regulatory measures that require improving energy efficiency, reducing emissions and safeguarding security of supply, or the anticipation of compliance with environmental or energy regulations, may lead firms outside the energy sector and its suppliers to invest in energy R&D. Yet, Costa-Campi et al. (2015b), in an analysis of the determinants of innovation in energy efficiency, show internal R&D not to be a significant variable. In contrast, Cagno et al. (2015) show that the more innovative firms, with a higher level of internal R&D and making greater use of open innovation practices, are more energy efficient.

## 3. MODEL, VARIABLES AND DATA

### 3.1. Model and variables

To carry out the empirical analysis, we use the following model:

$$R\&D_{it} = \beta_0 + \beta_1 C_{it} + \beta_2 S_{it} + \beta_3 F_{it} + \beta_4 P_{it} + \mu_i + e_{it} \quad (1)$$

where R&D refers to business energy R&D expenditure and C, S, F and P are explanatory and control variables for R&D investment, in general, and for energy R&D, in particular.

In the first set of variables, C, we, first, include those control variables that have been considered determinants of general R&D expenditure at the industry-level (Cohen, 2010). We use the amount of sales to control for demand and we also include the participation of foreign capital. Second, industries differ in their degree of energy intensity. These differences may have effects on decisions concerning specific expenditure in energy R&D.

The second variable, S, is the amount of products from manufacturing sectors acquired by firms of the sector “Electricity, gas, steam and air conditioning supply” (NACE Rev. 2 Classification, 35). This variable, a measure of intermediate consumption by energy industry, allows us to analyse the role played by suppliers in energy R&D investment, given that according to the literature is likely to be significant.

The third set of variables, F, corresponds to innovations in energy efficiency, the other key factor that may account for energy R&D in non-energy industries. We specifically include the proportion of firms that attach great importance to the innovation objective of reducing their energy costs. In addition, we examine the effects of the importance attached to the innovation objective of preventing an environmental impact on investments in energy R&D.

Finally, we include a set of variables, P, to examine the effect of different policy instruments on the promotion of energy R&D. First, we consider public financing of business R&D. However, the amount of public subsidies specifically granted to energy R&D is not available and so, as a proxy, we have included total public support to business R&D. Second, we take into account the potential effects of energy taxes. Finally, we include innovating with the objective of meeting environmental, health and safety regulatory requirements as a factor that may explain R&D expenditure in energy, particularly as regards environmental norms.

In addition to these explanatory variables, we also take into account in the estimations time-invariant and unobservable specific industry characteristics and time effects to control for cyclical change.

### 3.2. Data

In this paper, we use energy R&D investment at the industry-level for a set of manufacturing sectors as our dependent variable. The determinants of total R&D investment at both firm- and industry-levels have been extensively examined in the literature on the economics of innovation (Cohen, 2010). However, data on energy R&D are not usually available (GEA, 2012) given that private R&D expenditure is not usually reported by technology (Veugelers, 2012).

However, in the Spanish version of the Community Innovation Survey (CIS), since 2008 firms have been asked to classify their internal R&D expenditure according to its socio-economic objective, in line with the criteria employed in the Frascati Manual (OECD, 2002). Specifically, firms are required to distribute their R&D expenditure between fourteen socio-economic objectives (SEO), according to the specific purpose of the R&D programme or project. One of these objectives is the production, distribution and rational utilisation of energy. Specifically, SEO 5 covers: "research into the production, storage, transportation, distribution and rational use of all forms of energy. It also includes research on processes designed to increase the efficiency of energy production and distribution, and the study of energy conservation. It does not include research relating to prospecting (SEO 1) neither research into vehicle and engine propulsion (SEO 7)" (OECD, 2012). Likewise, this SEO does not include research into the control and care of the environment, an area that corresponds to SEO 3.

This information provided directly by the Spanish Institute of Statistics allows us to distinguish between energy R&D investment and non-energy R&D for 21 sectors. According to this information, almost 195 million euros were devoted to energy R&D by manufacturing firms in 2013. This amount is greater than the 149.2 million euros of total internal R&D invested by the utilities themselves (NACE 35 and 36).

All manufacturing industries reported investing in energy R&D. The main investors in terms of their weight in the total energy R&D are electrical equipment manufacturers, machinery and equipment manufacturers, chemical producers and fabricated metal product manufacturers. As for the weight of energy R&D in the total internal R&D of each sector (Table 1), the leading two sectors are the same: electrical equipment manufacturers, and machinery and equipment manufacturers.

Table 1

In addition to the limitations affecting the dependent variable, we also encountered difficulties obtaining information about the explanatory variables. In this paper, we have built a comprehensive dataset for 21 manufacturing sectors for the period 2008–2013 from five surveys conducted by the Spanish Institute of Statistics (see Table 2 for descriptive statistics). The surveys used were the following: the R&D Survey and the Technological Innovation Survey (the Spanish version of the CIS), which as well as providing details of total internal R&D and energy R&D, provide information about the main characteristics of the technological innovations made by firms and sectors; the Industrial Companies Survey, which collects annual information about the main characteristics of the firms and sectors (including number of employees, sales and export figures) and about the acquisition of intermediate inputs (including electricity, gas and other energy products); the Environmental Tax Account, from which we draw information about the energy and pollution taxes paid by each industrial sector; and, finally, the Use Table of the Input-Output framework, which provides information about the intermediate consumption of products from other industries by the utilities sector.

[Insert Table 2 around here]

## 4. RESULTS

We use a panel data set of 21 Spanish manufacturing sectors for the period 2008–2013 to examine the main drivers of energy R&D investment. Panel data estimations have the advantage of accounting for individual heterogeneity. However, as some of the independent variables show very little variation over time, we have estimated a random effects model.

The main results are presented in Table 3. The correlation between some of the independent variables is very high and, so, we have included some of them separately in the estimations. However, we have also conducted an estimation with all the explanatory variables. Moreover, to minimise endogeneity concerns, we have carried out various complementary estimations using lags of some of the independent variables, including public funds and the meeting of regulatory requirements. The results, though, remained largely unchanged.

Our main findings can be summarised as follows. First, even when controlling for sales, there is a positive relationship between the intermediate consumption of manufacturing products by utilities and energy R&D. In line with the literature, this result shows the significant role that suppliers have in developing energy R&D. Second, R&D investment by non-energy firms does not seem to be related to the innovation objective of achieving greater energy efficiency. Likewise, investment is not related to the innovation objective of reducing a firm's environmental impact.

Third, we include three instruments of public policy – public subsidies to business R&D projects, energy taxes and meeting environmental, health and safety regulatory requirements – in the estimations that might be related to the energy R&D expenditure of manufacturing sectors. Our results suggest that only public funds have a positive relationship with R&D investment. Nevertheless, some caution is required here because of the lack of information regarding the number of subsidies addressed solely to energy

R&D projects. Moreover, because of endogeneity concerns, these results should be interpreted principally as correlations and not necessarily as causal relationships.

Finally, by way of a robustness check, we have carried out a "placebo" test using as a dependent variable total R&D expenditure instead of R&D expenditure on energy. The results (last column of Table 3) show that sales, foreign capital and public R&D subsidies are statistically significant. Indeed, according to the literature, each of these variables is an explanatory factor of R&D expenditure. In contrast, the variable that captures intermediate consumption of utilities is not significant. As such, this estimation seems to indicate that some of the factors that account for investments dedicated specifically to energy R&D differ from those that account for investments in total R&D.

[Insert Table 3 around here]

## 5. CONCLUSIONS

The objective of this paper has been to contribute to the literature on energy economics by examining the drivers of energy R&D in non-energy industries. Although R&D is one of the main variables considered when analysing the economics of innovation, data constraints have substantially limited empirical analyses of investment in energy R&D by non-energy sectors.

To examine these drivers, we have compiled a database with information taken from several sources concerning innovation, energy and the economic characteristics of sectors. With this information, we have carried out an empirical analysis with panel data for 21 manufacturing sectors in Spain for the period 2008–2013.

The data on the amount of R&D investment made in energy by manufacturing sectors show the importance of including sectors other than the energy utilities in studies of energy R&D and its main drivers. The results from the empirical analysis point, first, to the important role played by suppliers in the overall volume of energy R&D. Second, R&D investment by non-energy firms does not seem to be related to the innovation objective of improving energy efficiency. The estimations also suggest that, among the three policy instruments examined, only public funding of business R&D is related to R&D investment in energy by non-energy industries.

These results have several policy implications in terms of how best to foster energy R&D and stress the necessity of considering the total effort in energy R&D when defining public policies. Overall, to improve R&D effort and innovation in energy requires an increase in cooperation between energy supply firms, firms in related industries and public institutions and agents.

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Table 1. Business R&D investment with an energy objective (weight on the total internal R&D of each sector, in %). Spain (average 2008–2013)

| | |
|---|---|
| Food, beverages and tobacco products (CNAE 10, 11, 12) | 6.95 |
| Textiles (CNAE 13) | 6.71 |
| Wearing apparel (CNAE 14) | 2.96 |
| Leather and related product (CNAE 15) | 12.11 |
| Wood and products of wood and cork (CNAE 16) | 6.53 |
| Paper and paper products (CNAE 17) | 9.31 |
| Printing and reproduction of recorded media (CNAE 18) | 6.36 |
| Chemicals and chemical products (CNAE 20) | 8.76 |
| Basic pharmaceutical products and pharmaceutical preparations (CNAE 21) | 3.40 |
| Rubber and plastic products (CNAE 22) | 6.01 |
| Other non-metallic mineral products (CNAE 23) | 6.54 |
| Basic metals (CNAE 24) | 8.08 |
| Fabricated metal products, except machinery and equipment (CNAE 25) | 6.55 |
| Computer, electronic, and optical products (CNAE 26) | 11.68 |
| Electrical equipment (CNAE 27) | 22.57 |
| Machinery and equipment n.e.c (CNAE 28) | 14.08 |
| Motor vehicles, trailers and semi-trailers (CNAE 29) | 2.85 |
| Other transport equipment (CNAE 30) | 1.24 |
| Furniture (CNAE 31) | 4.46 |
| Other manufacturing activities (CNAE 32) | 1.27 |
| Repair and installation of machinery and equipment (CNAE 33) | 10.59 |
| TOTAL INDUSTRY | 9.64 |

Source: Based on INE

CNAE: Spanish Statistical Classification of Economic Activities

Table 2. Summary statistics.

| Variable | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| LRDNEREGY: R&D expenditure in energy (in logs) | 126 | 15.223 | 1.599 | 8.783 | 18.025 |
| LSALES: Sales (in logs) | 126 | 18.367 | 1.230 | 16.113 | 20.937 |
| FOREIGN: Foreign capital (% participation) | 125 | 0.103 | 0.072 | 0.008 | 0.298 |
| LADQPE: Acquisition of energy products (in logs) | 126 | 12.487 | 1.289 | 10.486 | 14.731 |
| LFUNDS: Public R&D subsidies (in logs) | 126 | 8.931 | 1.455 | 3.178 | 12.212 |
| LSUPPL: Acquisition of intermediate products by utilities (in logs) | 120 | 3.445 | 2.438 | -1.204 | 7.499 |
| OBENERGY: Objective of innovation: Reduce energy per unit output (% of firms that consider this to be of high importance) | 126 | 16.098 | 5.439 | 3.20 | 30.598 |
| OBENVIR: Objective of innovation: Reduce environmental impact (% of firms that consider this to be of high importance) | 126 | 21.991 | 7.493 | 2.70 | 42.21 |
| OBREG: Objective of innovation: Meet regulatory requirements (% of firms that consider this to be of high importance) | 126 | 27.180 | 7.234 | 3.39 | 45.82 |
| LIMPE: Energy taxes (in logs) | 96 | 3.710 | 1.011 | 1.253 | 5.515 |

Note: the information for LIMPE is only available for the period 2008–2012

Table 3. Estimations of energy R&D expenditure (LRDENERGY)

| | (1) | (2) | (3) | (4) | (5) | (6) R&D total |
|---|---|---|---|---|---|---|
| LSALES | 0.208 | 0.137 | 0.133 | 0.135 | 0.196 | 0.186*** |
| | (0.128) | (0.154) | (0.152) | (0.154) | (0.148) | (0.067) |
| FOREIGN | 3.528* | 6.435** | 7.294*** | 7.018*** | 3.000 | 2.590*** |
| | (2.123) | (2.838) | (2.733) | (2.715) | (2.281) | (0.985) |
| LADQPE | -0.241 | 0.070 | 0.125 | 0.107 | -0.159 | 0.029 |
| | (0.266) | (0.159) | (0.153) | (0.149) | (0.277) | (0.114) |
| LFUNDS | 0.447*** | 0.290** | 0.306** | 0.294** | 0.443*** | 0.417*** |
| | (0.120) | (0.130) | (0.129) | (0.131) | (0.134) | (0.057) |
| LSUPPL | 0.219*** | 0.236*** | 0.244*** | 0.238*** | 0.152*** | -0.012 |
| | (0.053) | (0.071) | (0.071) | (0.071) | (0.060) | (0.021) |
| OBENERGY | -0.004 | 0.020 | | | | -0.005 |
| | (0.026) | (0.289) | | | | (0.007) |
| OBENVIR | -0.145 | | -0.009 | | | 0.001 |
| | (0.224) | | (0.222) | | | (0.001) |
| OBREG | 0.160 | | | 0.002 | | 0.003 |
| | (0.019) | | | (0.017) | | (0.005) |
| LIMPE | 0.467 | | | | 0.349 | 0.078 |
| | (0.296) | | | | (0.316) | (0.106) |
| Constant | 7.552** | 7.369* | 6.981* | 7.086* | 7.561* | 3.361* |
| | (3.683) | (3.821) | (3.752) | (3.802) | (4.144) | (1.915) |
| Observations | 95 | 119 | 119 | 119 | 95 | 95 |
| Number of groups | 16 | 20 | 20 | 20 | 16 | 16 |
| $R^2$ | 0.671 | 0.616 | 0.621 | 0.617 | 0.625 | 0.864 |
| $R^2$ within | 0.007 | 0.014 | 0.009 | 0.010 | 0.017 | 0.447 |
| $R^2$ between | 0.858 | 0.818 | 0.829 | 0.822 | 0.783 | 0.883 |

Note: the information for LIMPE is only available for the period 2008–2012. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

**2016/30, Di Cosmo, V.; Malaguzzi Valeri, L.**: “Wind, storage, interconnection and the cost of electricity”

**2017**

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