Energy-efficient innovation drivers: The two sides of energy scarcity

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Overview

The paper addresses the relationship between energy scarcity and energy-efficient innovation (EEI), a key ingredient of sustainable growth. Energy scarcity may hit even interconnected advanced economies, through high energy prices and a reduced supply security (Bazilian, Sovacool, & Miller, 2013; Cian, Sferra, & Tavoni, 2013). Understanding whether EEI is related to energy scarcity, and to which conditions, is necessary to decide on the most appropriate public policies in this field. The impact of energy scarcity on EEI is examined through two theoretical lenses: induced technical change (i.e. role of economic incentives), and public attention toward the scarcity and energy-related issues (i.e. role of intrinsic attitudes). In order to learn about the relevance of the two theories for explaining EEI we make use of both firm- and industry-level econometric models. The empirical setting is offered by a cross-sectional sample of 43.989 firms and 21 industries located in 9 European countries (2005-2008 period). The key source of information on EEI is the Community Innovation Survey[1] (CIS) of the European Commission, which included items on EEI and other types of innovation. The CIS dataset has then been matched with supplementary data sources.

The paper leans on the view of EEI as a relevant instance of resource-saving innovation in response to natural resource scarcity (Nelissen & Requate, 2007), although with a possible role for rebound effects and environmental policy. This perspective has been recognized already by the induced innovation literature (Hotelling, 1931; Jaffe, Newell, & Stavins, 2003, 2002; Newell, Jaffe, & Stavins, 1999). Nevertheless, a crucial enlargement of the viewpoint arises when environment and natural resources are described as natural capital, a concept that has been widely acknowledged only recently. While the natural capital debate admits that resources should be exploited in optimal manner, natural resources preservation is emphasised as a goal in itself (Bretschger, 2005). Therefore, actions directed toward conservation, including EEI, can be better described as a combination of extrinsic incentives and intrinsic attitude, as pointed out by behavioural studies of conservation (Scarlett, Boyd, Brittain, Shabman, & Brennan, 2013, p. 29-30). This behavioural nature is difficult to quantify. Instead, the manifestation of that can be captured by observing public attentiveness, a concept commonly used in political science (e.g. Newig, 2004). In this case, public attentiveness to energy scarcity represents a measure of contemporary interest rate of people in energy scarcity, reflecting their attitude, which is argued to be a driver of EEI.

In order to investigate the explaining strengths of the two theories, which are not necessarily competing, we model together both EEI that improves the firm's own energy efficiency ("process" EEI) and EEI that introduces an energy-saving "product" for firm's customers. Four research hypotheses are tested, after controlling for industry- and firm-specific characteristics. ***(H1a)*** Firms that are located in countries with higher energy prices are more likely to develop an EEI, ***(H1b)*** which is even more accentuated for the ones that belong to more energy-intensive industries. ***(H2)*** Firms that are located in countries that are characterized by a greater awareness of, i.e. attentiveness to energy-related challenges are more likely to develop an EEI. ***(H3)*** Energy price and public attention toward energy-related issues have a positive interaction effect on EEI.

Finally, our empirical results are expected to contribute to the debate on the role of resource scarcity as a determinant of resource-saving innovation and even more on alternative channels through which resource scarcity may spur innovation. Further, our findings are expected to help policy makers in identifying industries and countries that are less likely to enter the EEI arena, and in designing corresponding policies (Berrone, Fosfuri, Gelabert, & Gomez-Mejia, 2013; Courvisanos, 2005; Jaffe et al., 2002).

Methods and Data

In order to measure the EEI performances of firms and industries we use information collected in the context of the 2009 CIS survey. The CIS questionnaire included a section on environmental benefits of innovations introduced in 2006-2008. The section items were carefully designed to elicit sound information from respondents (Arundel & Kemp, 2009; Horbach,

[1] The Community Innovation Survey (CIS) are a series of surveys executed by national statistical offices throughout the European Union and in Norway and Iceland. The harmonized surveys are designed to give information on the innovativeness of different sectors and regions.

Rammer, & Rennings, 2012). In particular the dataset observes whether a firm has introduced an EEI within its borders or an energy-saving product innovation for customers. In order to test the four hypotheses, firstly we estimate a hierarchical OLS Grouped Data regression, i.e. an industry-level model that returns the firm's probability to introduce a process EEI. The sample consists of 21 industry and service sectors and 9 European countries. The number of observations is small **(**145, after excluding some missing observations), but it is acceptable as the sample aggregates a high number of observations.

Dependent variable: ***PEEI*** is the percentage of firms that introduced energy-efficient innovation out of the total number of firms in the same industry and country (2006-2008). ***PEEI*** is transformed using natural logarithm to ***PEEI_ln*** (***PEEI_ln***=*ln(PEEI/(1-PEEI))*, in order to solve the problem of dependent variable as a frequency and to make it unbounded, (see Cameron and Trivedi, 2009, p. 473).
Explanatory variables: They are observed in a pre-sample period, i.e. 2005, to reduce the endogeneity risks. The country's energy price and its interaction with the country-industry's energy intensity are used to test *(H1a)* and *(H1b)*. Energy price, ***EP***, is proxied by the country's electricity price (and gas price as a robustness check), as sourced by Eurostat. Notably, ***EIS***, the energy input share of the industry in a given country, i.e. energy input expenditures per unit of value added as sourced by the EU Klems Growth and Productivity Accounts Database (http://www.euklems.net/), can be shown to be equal to the cross-product between energy price index and energy intensity. Indicator of the country's public attentiveness toward energy, energy scarcity and conservation, ***PA***, is introduced distinctively and in interaction with the other explanatory variable, i.e. energy price (after centering both variables), to test *(H2)* and *(H3)*, respectively. The construction of ***PA*** variables is carried out using a novel approach for developing public attentiveness indicators, i.e. a web-crawling method, which takes advantage of publicly available Search Volume Index (SVI), created with Google Trends facility (www.google.com/trends/) (e.g. Gbadji, Gailly, & Schwienbacher, 2011; Ripberger, 2011).
Control variable: ***PI***, i.e. the percentage of firms that introduced any kind of innovation in the same timeframe, in the same industry and country. It is expected to capture most of the unobserved innovation heterogeneity between countries and industries, i.e. unobserved variables such as market structure, sector appropriability, average firm size, average R&D expenditures, country's distance from technological frontier, etc. ***RENREG*** is a policy variable, which is the percentage of firms in the same industry and country, which introduced an environmental innovation in response exclusively to environmental regulations or governmental financial incentives for environmental innovation. ***PPP2005*** is the gross domestic product converted to international dollars using purchasing power parity rates, used to control for country effects on the EEI (source: The World Bank).

As a further robustness check and as a mean to fully exploit firm-level information on EEI, a firm-level model is developed. Logit model is used to represent firms as facing discrete choices about EEI. The sample is equivalent to the one used for the industry-level analysis. *Dependent variable:* EEI is a binary variable, set equal to 1 if the firm has introduced an EEI. *Explanatory and control variables*, in addition to variables that have been already discussed for the industry-level analysis, include further firm-level controls, e.g. size as measured by the number of employees, R&D intensity, etc.

Results

Preliminary results on the industry-level analysis can be summarized as follows. The coefficient of determination (R-squared) is reasonably high (0.6605), meaning that the great portion of variance of the dependent variable is explained by the model. Our findings offer a hint that (*H1a*) should be accepted. EEI appears to be a case of induced innovation, because energy price is found to have a significant and positive effect on EEI propensity other things being equal. That is even more so in case the sector of the firm's activity is highly energy intense, i.e. a higher energy price in the presence of large energy intensity induces industries to develop EEIs, which supports *(H1b)*. The results also show that public attentiveness toward energy spurs EEI, which endorses *(H2)*. At this stage of analysis, however, the combined effect of high energy price and high public attention toward energy is not statistically significant. As to the firm-level analysis, very preliminary estimates confirm these finding.

Conclusions

The initial phase of the empirical study, which should support understanding of the drivers of energy-efficient innovation, has been conducted. The industry-level model is showing that the market is unlikely to fail in stimulating energy conservation. Namely, there is a positive relationship between the energy input share of a sector and EEI. Those firms that are likely to bear greater costs of energy wastage, because they belong to more energy intensive industries, are more likely to introduce EEI. The public attention toward energy-related issues has also been found to spur energy-efficient innovation. Finally, we look forward to completing the estimates of core models and to improving the results by analysing product and process EEI separately, and small-medium and large enterprises separately. Additionally we will submit our findings to robustness checks, e.g. by making use of alternative indicators of public attentiveness and environmental regulation. Based on a broader range of analyses, we will elaborate on implications of our empirical findings both for research and policymaking.

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