Environmental innovation and its impact on employment

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Abstract

This paper examines the relationship between environmental innovation and employment from firm-level evidence. The data is taken from the Spanish Technological Innovation Panel (PITEC) survey and it covers the period of 2007-2011. The increasing relevance of environmental issues for the Spanish economy, its unemployment problem and the uniqueness of the Spanish innovation structure (De Marchi, 2012) make it a proper and interesting context to investigate environmental innovation dynamics. Based on our regression results on more than five thousand firms, we find an increase in employment for environmental innovators, as compared to non-environmental innovators and non-innovators, both before and during the Spanish crisis that started in 2008. The increase in employment is higher for dirty industries. Our results show that no matter firms introduce environmental innovation voluntarily or merely to comply with regulations, they create jobs. In addition, our results show a positive and significant relationship between employment and firms that report an increase or at least no change in the degree of importance paid to environmental innovation. This analysis has major policy implications on the Spanish economy, which is experiencing a severe unemployment problem.

Key words: environmental innovation, employment, cross-section.

Introduction

Undesirable environmental consequences from human activities advance at an alarming speed (Pacala & Socolow, 2004). From climate change and global warming leading to melting ice cap, to stronger storms and hurricanes and major flooding (Patz, Campbell-Lendrum, Holloway, & Foley, 2006; Easterling et al., 2000) or even to China's toxic air pollution that is so bad now it resembles a 'nuclear winter' (Kaiman, 2014). And the list continues on. Our technologies have indeed helped elevate our lives in an unprecedented manner, but we will soon outstrip these advantages if growth continues in this way.

As corporations have been portrayed as one of the key causes of current environmental state, numerous firms take on active roles in environmental management (Walker & Wan, 2012). Different actions are set out in favor of environmental protection and improvement. Some firms merely adopt the management of the environment, while some are being more strategic by encompassing environmental and economic aspects together through environmental innovation development. Not only because corporations are being scrutinized and put under pressures to respond, but also the increasing regulatory pressures and public incentives control and induce firms towards innovation developments with positive environmental implications (Bilbao-Osorio et al., 2012; Johnstone, Hascic, & Ostertag, 2008).

From the perspective of the economy at large, one of the topics commonly addressed during political debates concerns the question of how firms' transformations towards being green affect economic performance and employment (Rennings, Ziegler & Zwick, 2004). For instance, the Strategy EU2020 sets out guidelines for a new economy where the crisis should be turned into an opportunity for creating jobs, building a smarter and greener economy that rest on innovation and better use of resources (Europe 2020, 2014). Innovation literature and existing empirical evidence shows that the relationship between technological progress and job creation is clearly not negative (Harrison et al., 2008; Rennings et al., 2004). In contrast, environmental innovation leads to an increase, a decrease or even no effect on job creation. For instance, environmental product innovation has a positive effect on employment (Rennings et al., 2004); while cost reductions envisaged by environmental innovation create job losses and innovations purely motivated by environmental goals have no effect (Rennings & Zwick, 2002). With the few empirical works that exist, these studies are weak because many works lie in case study methodology (Rennings et al., 2004). The consequences of green innovation on job creation are thus of our particular interest as the relationship is not particularly well-known and the views and impacts indeed spur ongoing debate.

In an effort to resolve this seeming paradox, the focus of our paper is to estimate the effect of environmental innovation on job creation from the best data available at hand, considering the scarcity nature of environmental innovation data (Horbach & Rennings, 2013). We base our study on the Spanish Technological Innovation Panel (PITEC) survey of more than five thousand firms during the period of 2007-2011. PITEC is based on the Community Innovation Survey (CIS) framework, which is a valid tool in studying innovation and is one of the most used datasets for studying innovation (Laursen & Salter, 2004, 2006). It is carried out yearly by the Spanish National Statistics Institute (INE) in collaboration with the Spanish Science and Technology Foundation (FECYT) and the

Foundation for Technological Innovation (COTEC). The paper contributes in several important ways.

First, this paper tries to fill the gap, at least partially, by providing more empirical evidence about the impact of environmental innovation on job creation at firm-level. As PITEC is based on CIS framework, it enables direct comparisons of this work with previous empirical literature as well as future research using similar datasets. Not only that this paper helps to enlarge the very few findings that exist in this field, but it is also useful towards the design of micro-policies that will help to improve growth in employment, especially the employment crisis in Spain.

Second, we address criticisms from prior research concerning the needs to expand the study on firm's environmental friendliness to other settings outside the predominant U.S. sample (Walker & Wan, 2012). In this paper, we focus on Spanish firms. Spain is a moderate innovator (Hollanders & Es-Sadki, 2013) with gross domestic R&D expenditure in 2011 roughly 0.5% below the European Union (EU) average (Eurostat, 2013), yet Spain is very advanced in terms of environmental innovation. In 2011, Spain's composite index of eco-innovation scoreboard was 28% above the EU27 average (EIO, 2011; Sorli & Zambrano, 2011). Many environmental efforts both at national- and autonomous community-level have continued to offer a range of strategies and documents related to innovation and sustainable development such as an environmental technology platform (PLANETA) to promote green growth and co-operation on environmental technologies among public and private research organizations (OECD, 2012). To date, voluntary green certifications have been adopted countrywide and have received a high recognition among Spanish firms. Spain is the first country in Europe and the third in the world with 16,433 ISO14001 certificates. The number of eco-management and audit scheme (EMAS) certified organizations is as well very high, with 1,235 certified workplaces (Sorli & Zambrano, 2011). Moreover, Spain aims to use environmental innovation to help boost economic growth (Barranco, 2013). The expenditures on environmental protection in 2011 stand at 2.39 million Euros, representing a 0.2% increase from the previous year (INE, 2013). The increasing relevance of environmental issues for the Spanish economy, its unemployment problem and the uniqueness of the Spanish innovation structure (De Marchi, 2012) make it a proper and interesting context to investigate environmental innovation dynamics.

Lastly, we present the results in aggregate manner like in previous studies as well as distinguishing between types of environmental innovation that exists. We decompose environmental innovation into voluntary and compliance-driven.

From our results, we can establish a 'trace' of an increase in employment for environmental innovators, as compared to non-environmental innovators and non-innovators, both before and during the Spanish crisis. The increase in employment is higher for dirty industries. Our results show that no matter firms develop environmental innovation in order to comply to regulations or voluntarily, the bottom line is that they create jobs. In addition, our results show a positive and significant relationship between employment and firms that report an increase or at least no change in the degree of importance paid to environmental innovation.

The remainder of the paper is organized into four parts. Part two focuses on the literature explaining what environmental innovation is and its relation to job creation at firm-level. In Part three, we present the data and methods. In Part four, we analyze the results. Part five discusses and part six concludes.

Literature review and hypotheses

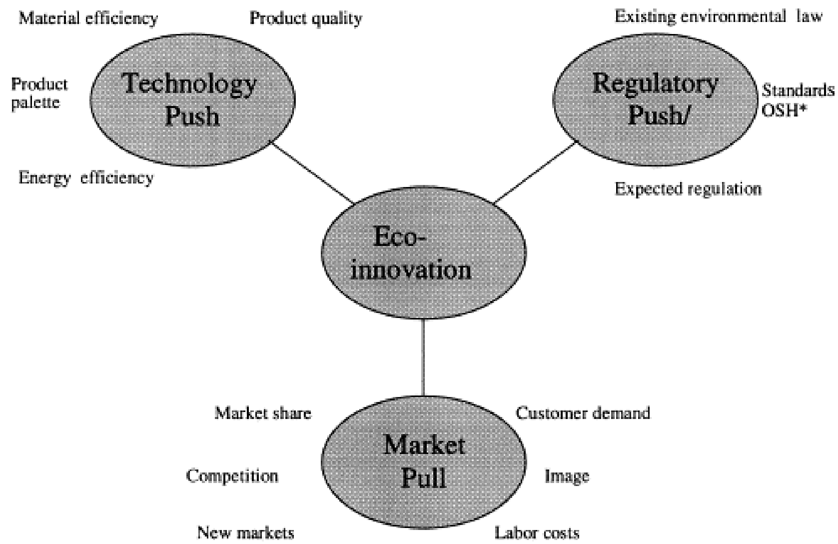
What is environmental innovation?

The terms eco-innovation, environmental innovation and green innovation have been and are still used synonymously (Tietze, Schiederig, & Herstatt, 2011). In this paper, we adopt the definition below.

> "Environmental innovations consist of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental damage. Environmental innovations may be developed with or without the explicit aim of reducing environmental damage. They also may be motivated by the usual business goals such as reducing costs or enhancing product quality. Many environmental innovations combine an environmental benefit with a benefit for the establishment or user" (Hemmelskamp, 1997; Rennings, 2000; Rennings et al., 2004: 376).

Environmental innovation is similar to innovation in general (van Leeuwen & Mohnen, 2013). Yet, unlike conventional innovations, technology-push and market-pull factors alone do not provide enough incentives for firms to be engaged in environmental innovation (Rennings, 2000). Environmental innovation produces the usual spillovers of innovations in general as well as creates less environmental costs. While the society as a whole benefits from environmental innovation, the cost is borne by a firm. Despite the fact that a certain green innovation can be marketed successfully, firms' ability to appropriate profits from such innovation can be difficult if the environmental benefits have a public good character or the corresponding knowledge is easily accessible. Additionally, as long as the markets do not punish environmental harmful impacts, competition between environmental innovators versus non-environmental innovations is distorted. Market forces alone do not provide sufficient innovation incentives and that consumers' willingness to pay for environmental features would be too low. This is what Rennings (2000) calls 'double externality problem'. Consequently, this double externality problem leads to an increasing importance of regulatory framework since such externalities result in suboptimal investment in environmental innovations. Environmental policy becomes another important driving force for green innovations. This is the second peculiarity of the push/pull regulatory effect. See Figure 1. The model is in line with Porter Hypothesis that highlights the stringency of environmental regulations in triggering environmental innovations (Porter & van der Linde, 1995).

FIGURE 1
A model of the determinants of environmental innovation



Source: Rennings, 2000

Environmental innovation and employment

In recent years, environmental technologies have received a lot of attention from scholars and policymakers alike. Despite its importance, the study about the impact of environmental innovation on job creation at the macroeconomic-level is still rare (Pfeiffer & Rennings, 2001; Rennings et al., 2004) and very perplexed, notably when coupled with the effect from environmental policies.

On one hand, environmental regulations have created many new firms, in which according to the literature, firm entry is an important source of employment growth (Harrison et al., 2008). For example, a group of entrepreneurs saw an increase in environmental stringency as an opportunity and founded a new firm called LanzaTech in 2005. It develops and commercializes technologies that turn carbon monoxide into low-carbon fuels such as ethanol, and chemicals such as propylene for plastic. One of its most recent projects is with Baosteel, one of China's largest steel manufacturers. (LanzaTech, 2014; Tilley, 2014). On top of that, environmental regulations have resulted in entirely new industries such as those of 'green industry'. In many cases, green industry is characterized by substantial potential for growth. The latest report on environmental sector in Spain shows that employment in this sector has grown considerably despite economic and unemployment crisis. In 2011, employment in the sector represents 2.62% of the working population. The structural change in the society from Spanish's sustainable economy bill is also expected to create up to 2.8 million green jobs by 2020 (Jiménez Herrero & Leiva, 2011). In this regard, environmental innovation impact on employment is positive.

On the other hand, clean production reduces demand for material or energy and thus reduces demand for labor in these industries. The net effect of green innovation on employment is therefore uncertain (Pfeiffer & Rennings, 2001).

It is no doubt necessary to understand the impact of technological change at the macro-level (see Pfeiffer and Rennings (2001) for the discussion of green innovation on employment at the economy-level). However, it also makes sense to go down to the microlevel. After all, the change starts from individual firms. The remaining of the paper focuses only on firm-level effect.

Comparing with evidence of the impact of technological progress on labor demand at firm level, a basic distinction is drawn between product and process innovation. Both kinds of innovation can be associated with compensation effects (or employment stimulating effects) and displacement effects (or labor-saving effects) which reduce employment. (see Table 1, Harrison et al. (2008) and Dachs and Peters (2014) for further detail).

TABLE 1
Effects of product and process innovation on employment at firm level

	Displacement effect	**Compensation effect**
Product innovation	*Productivity effect*: (-): New products require less (or more) labor input *Indirect demand effect*: (-): Decrease in demand of existing substitutes	*Direct demand effect:* (+): New products increase overall demand *Indirect demand effect*: (+): Increase in demand of existing complementary products
Process innovation	*Productivity effect*: (-): Less labor input for a given output	*Price effect*: (+): Cost reduction passed on to price expands demand

Source: Dachs & Peters, 2014

Existing studies differ widely in terms of modeling strategies and methods. A study by Harrison et al. (2008) agrees with the already existing literature. Their results illustrate a strong positive effect of product innovation on employment. Bogliacino and Pianta (2010) distinguish between innovation's technological and cost competitiveness. They find that technological competitiveness has a significant positive effect on labor inputs, while cost competitiveness has a negative impact. Lachenmaier and Rottman (2011) find a positive effect on employment growth for both product and process innovation, with process innovation having higher effect than product innovation. Dachs and Peters (2014) show that foreign-owned firms experience higher job losses than domestically-owned firms due to general productivity increases and process innovation. At the same time, the impact of product innovation on employment is larger for foreign-owned firms. In general, results show innovative firms clearly have higher employment record (Dachs & Petersm 2014; Harrison et al., 2008; Lachenmaier & Rottman, 2011).

The very few prior environmental innovation studies are in line with conventional innovation literature. Positive effects of environmental-innovations on employment are detected. Horbach and Rennings (2013) show that though environmental product innovation does not trigger employment growth, green process innovation leads to job creation, particularly for green process innovations that lead to material and energy savings. Rennings et al. (2004) find that product environmental-innovations have a positive effect on the probability of an employment increase. Rennings and Zwick (2002) illustrate that environmental innovations have a small but positive effect on employment. The shift from end-of-pipe technologies to cleaner production creates jobs. Overall, there appears to be a positive relationship between employment and environmental innovation.

Although firms might be doing the similar type of environmental innovation because, say, they are located in the same region and are subject to the same set of environmental regulations, their impact on employment may differ because of the ex ante heterogeneity among them. Certain industries may be more likely than other industries to increase employment, given that they do environmental innovations. Specifically, we focus on one source of ex ante heterogeneity across firms, which is the industry firms belong to. This is whether or not the firms belong to a so-called 'dirty' or 'clean' industry. We base our typology on not only the pollution level but also toxins as according to the latest Toxic Release Inventory (TRI)'s annual report of 2011 and the US Environmental Protection Agency (EPA). See Appendix 1 for further detail. This typology is more appropriate to study environmental innovation than the usual manufacturing versus service industries in the traditional innovation.

Firms in dirty industries are more scrutinized by the public as well as are subject to stricter and more environmental regulations than firms in clean industries. As a result, they may have stronger internal environmental orientation. Environmental innovations for dirty firms may have a much substantial meaning than for clean firms. They may analyze new product development for the whole life cycle rather than symbolically such as the end-of-the-pipe technologies. For example, Dangelico and Pujani (2010) report that one of the managers in their study from the wood industry emphasizes going beyond 'cradle to grave' approach. He says that "the product development process in our company is strictly focused on eco-design and therefore on life cycle thinking… for the environmentally friendliness of our products, we use the necessary quantity of materials without exceeding in the use, we reduce the environmental impact of production process through the use of renewable energy and of water and energy efficient machineries… we use only FSC or PEFC certified wood… we try to create a network to obtain a short supply chain… products can be reused (with and without repairing),… collected, dissembled and components recycled… Our product is different from a 'cradle to grave' path because it follows a 'cradle to cradle logic'" (P. 478). Another manager from a chemical industry in Dangelico and Pujani (2010)'s study points out that "regulations represent for us constraints but also caution for avoiding risks of activity breakdown, money losses or damage to the company image" (P. 474). He further adds that "the reduction of packaging materials and of environmental risk is quantified and easily recognizable at the eyes of our main market, and so environmental innovations in products and packaging gives added value to our company" (P. 476).

Taken together, by being in a dirty industry, firms may feel stronger need to differentiate themselves more than clean firms in order to avoid being punished by the public from not being green or to capture the opportunities in the green markets. Furthermore, just the fact that these firms are in dirty industry, with the improved environmental technologies, the public might feel like these firms provide substantial change towards sustainability. This is as compared to clean industry where the public probably does not notice, care, or feel firms' environmental impact as much since the existing level of environmental footprint may be small. The public may respond to environmental innovation from dirty industry more positively. Subsequently, this new green product development may result in higher potential and higher substantial impact to market success and competitive advantage. We thus expect the effect of environmental innovation on employment to be stronger than for clean industries. We posit the hypothesis as follow:

H1: At firm-level, environmental innovators create more jobs than non-environmental innovators and non-innovators. This increase is greater for the so called 'dirty industries' than 'clean industries'.

Voluntary versus compliance-driven environmental innovation

The green business literature usually makes a distinction between firms that adopt a more proactive or voluntary stance, taking into account a variety of forces other than government regulations, versus firms that are compliance-driven with a mere aim to meet legal requirements (Buysse & Verbeke, 2003; Schot & Fischer, 1993). We distinguish between the different types of environmental innovation, not only because there exist different types of environmental innovation (Frondel, Horbach & Rennings, 2007; Kemp & Pearson, 2007; Rennings et al., 2004), but also the expected outcomes on employment are different (Horbach & Rennings, 2013). Consequently, we combine Renning's (2008) technology-push and market-pull factors together and call it 'voluntary', or we can also think of it as 'proactive'. The rationale behind is that firm's decision whether or not to develop environmental innovation is voluntary. The decision is not forced upon by law. While for regulatory-push factor, we call it 'compliance-driven environmental innovation'. In this case, firms develop environmental innovation to conform to legal requirements.

Theoretically and empirically, proactive corporate environmental strategies that go beyond compliance with environmental regulations are found to be associated with improved financial performance (Klassen & McLaughlin, 1996; Klassen & Whybark, 1999; Russo & Fouts, 1997) and competitive advantage (Aragón-Correa & Sharma, 2003). The literature also shows that there is a market for green products (Dangelico & Pujari, 2010; OECD, 2013). Dangelico and Pujari (2010) state that "the size of green markets is increasing and is likely to get bigger in the future" (p. 473). Green innovation indeed seems to have potential in leading firms to achieve growth.

Prior empirical evidence agrees with the above arguments. When the goal behind developing environmental innovation is driven by market share or to respond to competitors' actions, there is a positive effect on the probability of an employment change (Rennings et al., 2004). Moreover, environmental innovation that leads to material and energy savings induce cost savings which lead to higher competitiveness of firm, and subsequently, higher employment (Horbach & Rennings, 2013). As such, no matter the goal of environmental innovation is to increase market share, to improve the image, or to save costs, once it is a voluntary and proactive, we expect a positive impact on employment.

In contrast, some researchers argue that increased environmental regulations could lead to higher costs, unproductive investments or even a possible loss of competitive advantage (Walley & Whitehead, 1994). Firms' response to regulations may become very expensive when faced with rapidly evolving and increasingly complex and severe environmental regulations (Berry & Rondinelli, 1998). Others, such as Porter and van der Linde (1995) argue that stringent environmental regulations provide firms with opportunities for improved efficiency. It appears the effect on employment due to environmental regulations can go in both directions.

Horbach and Rennings (2013) illustrate that when environmental-innovation is driven by regulations, there is no significant increase in employment. Stringency of environmental policies is known to lead to more end-of-the-pipe type technologies

(Aragón-Correa & Sharma, 2003; Frondel et al., 2007; Hart, 1995). Rennings et al. (2004) show that the effect of end-of-the-pipe technologies on employment is negative. At the same time, Rennings et al. (2004) also show that environmental regulations in order to induce environmental innovation have both positive and negative influence on employment. As such, we expect compliance-driven to result in a lower level of employment increase as compared to voluntary-driven environmental innovation. We postulate the hypothesis as follows.

> *H2: Environmental innovators that develop environmental innovation voluntarily create more jobs than environmental innovators that develop environmental innovation due to compliance with environmental regulations.*

Data, methods and measures

Data

The sample of firms for this study is drawn from the Spanish Technological Innovation Panel (PITEC) survey[1]. It is carried out yearly by the Spanish National Statistics Institute (INE) in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). Most questions in the questionnaire are related to firms' innovation behavior in the preceding two years.

The use of PITEC survey provides several advantages. First, PITEC is a large-scale survey that offers the opportunity to study environmental innovation. Second, PITEC is based on the Community Innovation Survey (CIS) framework, one of the most used datasets for analyzing innovation (Laursen & Salter, 2004, 2006). Thus, PITEC is a valid tool in studying innovation and offers direct comparisons of this work with other works based on CIS.

At present, PITEC sample contains over 13,000 firms. The degree of representativeness of the population depends on firm size. The dataset is representative of the population for firms with more than 200 employees. However, the representativeness of firms with less than 200 employees is biased towards firms having external and/or internal R&D.

We combine PITEC survey of year 2011 together with PITEC surveys of 2007-2010, with 2011 as the latest available dataset. This helps to reduce the potential problem of common method variance (Podsakoff & Organ, 1986) and reverse causality (Wooldridge, 2013). Nonetheless, we perform Harman's one-factor test to check for potential common method variance. The results from unrotated principal component analysis with and without varimax rotation performed on all variables suggest no potential problem of common method variance. No single factor emerges and no factor accounts for a majority of variance (with 21.60% for the first factor).

We screen PITEC dataset three times in selecting firms. First, only those firms that exist from the period of 2007-2011 are selected due to the changing nature of the sample. Second, we drop petroleum industry as there are only two observations. Last, we drop

[1] The dataset, the questionnaire and the description of each variable is available free of charge at the website http://icono.fecyt.es/PITEC/Paginas/por_que.aspx

observations for which we cannot compute employment, environmental innovation and other essential information due to incomplete data. After applying these screens to the population, we end up with 5,137 firms for our study sample, without missing values.

Econometric model

According to the literature, a model based on a static estimation equation that uses cross-sectional data leads to problems. The high costs of hiring and firing, especially in European economies, are well-known arguments as to why there is a time lag between implementation of innovation and its effect on employment adjustments (Lachenmaier & Rottman, 2011). Other relevant studies also allow for an adjustment process by including lagged values of innovation (van Reenen, 1997). These authors test the relationship based on a panel data.

However, the changes in the questions in PITEC questionnaire pose challenges for inter-temporal analysis. Additionally, data on environmental innovation and other essential variables are available in a block of 2-year period. We thus base the construction of our econometric regression by adapting from Harrison et al. (2008)'s model and combine it with Lachenmaier and Rottman (2011). We assume the two-stage decision process in employment as in Konig et al., (1995) and Rennings et al., (2004), where firms first decide to invest in environmental innovation, and then decide to increase or decrease volume of labor input at a second stage. Our study focuses only on firms' second-stage employment decision. We do not consider why and how firms innovate and grow. We perform OLS with robust standard errors to account for heterogeneity and lack of normality. We regress log of employment level of firm *i* at time *t* on environmental innovation at time *t-1* that is referred to environmental innovation objectives in the last two years.

We perform additional robustness checks. We run our model with robust regression to address potential outlier problem. We run generalized linear model (GLM) to address the issue of heteroskedasticity. A different specification for our explanatory variable is also used. Instead of a dummy, we perform a factor analysis on the four environmental innovation objectives. We try adding controls to our model. For instance, we try controlling for the supply situation in the industry that can have potential influence on firms' decision to employ more or less employees, using the average labor cost per industry as provided INE's annual labor cost surveys. Furthermore, we run regressions with different specifications for our proxies for some control variables. The results are consistent.

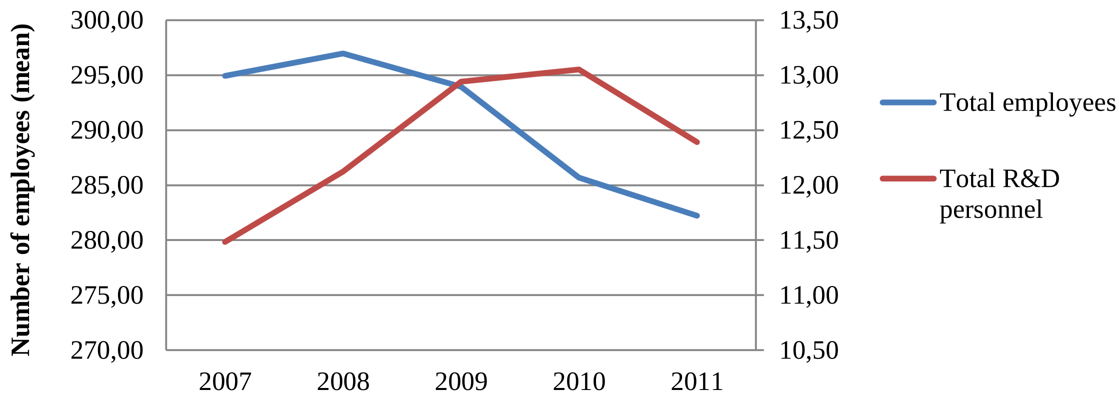
Dependent variable

The dependent variable, employment, is obtained from PITEC survey. The dataset provides very detailed information on employment such as total employment, total employment for internal R&D by occupation and by education level and whether or not they are full-time. Unfortunately, PITEC data is anonymized to avoid disclosure problems. We could not complement this dataset with external information.

Prior researchers (e.g., Harrison et al., 2008) use rate of employment growth as a proxy to test if innovation stimulates employment. In our study, however, we follow the approach of Lachenmaier and Rottman (2011) in using natural log of employees. Employment tends to be quite stable over time, as compared to for instance growth in sales. The use of our proxy is thus appropriate.

Figure 2 illustrates the trend of firm's total employment and total R&D personnel from 2007 to 2011. We can see that the trend in employment in Spain is decreasing. This is not surprising considering the Spanish crisis, particularly in employment. The number of R&D personnel also decreases but at a slower rate. Again, the result is to be expected, given Spain's overall decrease in expenditure on innovation, with the annual growth rate of -8.8% from 2010 to 2011 (INE, 2013).

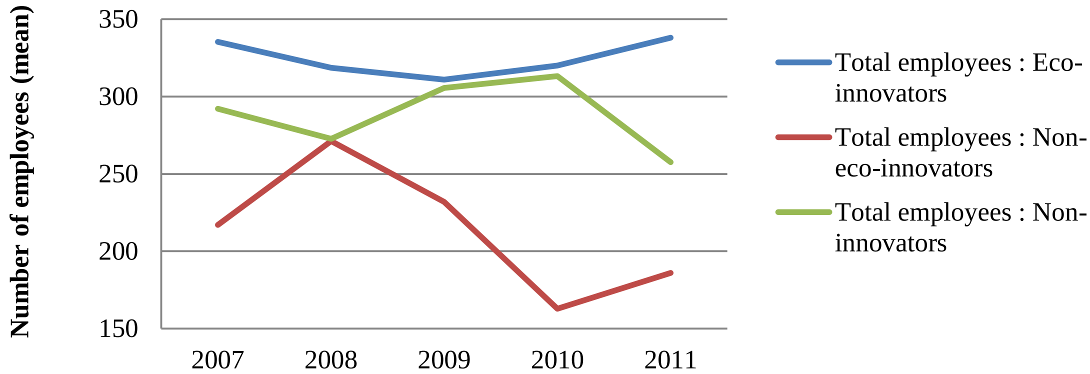
FIGURE 2
Total employees and total R&D personnel



We further break down the data into three types of firms to examine any differences. In this dataset, about 65.51% of firms are innovators. They are identified by their answer to the question regarding whether or not they have introduced innovation in the previous two years. Among these innovators, 73.40% are environmental-innovators. They are identified by their answers on the degree of importance paid to environmentally-related innovation objectives. It might seem that the number of green innovators in Spain is high in our sample. However, when we consider the fact that Spanish firms regard environmental issues highly, it is not surprising. Spain is the first country in Europe and the third in the world with 16,433 ISO14001 certificates. The number of eco-management and audit scheme (EMAS) certified organizations is as well very high, with 1,235 certified workplaces (Sorli & Zambrano, 2011).

In Figure 3, we show total employment for environmental-innovators, non-environmental innovators and non-innovators. Environmental-innovators were less affected by the Spanish crisis, with smaller rate of decrease from 2007 leading to 2009. They performed better than the other two types of firms in terms of employment, with an increasing trend from 2009 to 2011. Non-environmental-innovators were affected severely by the crisis, with the sharp decrease in employment. However, non-environmental-innovators performed better in terms of employment as compared to non-innovators, with an increasing trend from 2010 to 2011.

FIGURE 3
Total employees and total R&D personnel by types of firms



Explanatory variable

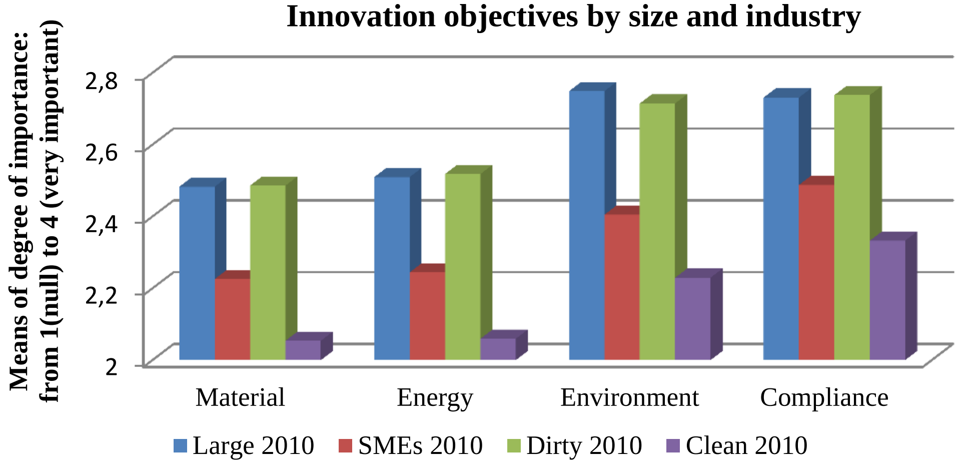
Our independent variable, environmental innovation, is based on a self-report data on the objectives of innovation firm introduced in the last two years. In many previous studies, environmental innovation has been commonly measured using questionnaire surveys (Anton et al., 2004; Christmann, 2000). Kemp and Pearson (2007) also suggest using a self-reported input-oriented data rather than using the extensively employed measures of environmental investments (inputs) or environmental patents (outputs) (Nameroff, Garant, & Albert, 2004). Both environmental R&D expenditures and environmental patents pose problems (Toshi et al., 2007). Drawing exact boundaries between different investment objectives is by no means straightforward (Grupp, 1998). Environmental R&D expenditures can be used to show how much is spent on equipment and processes that will result in environmentally-products and processes, but we do not know if they are spent on new to the market innovations or old standardized ones (Lázaro, Dorronsoro, Casas, Rodríguez & Sedano, 2008). R&D, in general, captures only parts of innovation. It is usually more important for high-tech products but less so for other types of innovation or in small firms (Kemp & Pearson, 2007). Particularly, roughly 70% of our sample is SMEs firms. Furthermore, the patent classification system has not yet provided specific categories for environmental patents. There is still no widely accepted agreement in the literature as to what constitutes environmental technology. Green patent identification is based solely on researchers' judgments and understandings (Kemp & Pearson, 2007) and eco-patents mainly measure identifiable inventions that are mostly end-of-the-pipe technologies or green product innovations (Arundel & Kemp, 2009; Kemp & Pearson, 2007). Many innovations that take the form of changes in production processes such as 'clean production' are harder to identify and patent. Therefore, not all environmental innovations are patented. In addition, patenting activity in Spain, including eco-patenting is low. Spain has one of the lowest ratios of patents per million habitants in Europe according to the European patent office (Sorli & Zambrano, 2011). As such, these proxies could lead to over- or under-estimation of innovation (De Marchi, 2012); we can argue that the use of objective, as in our study, is not inferior to other proxies of environmental innovation.

PITEC provides information on the degree of importance of the following firm's innovation objectives: 1) using less material; (2) using less energy; (3) lower impact on the environment; and (4) complying with the requirements on environment. The degree of importance for each objective is based on a Likert scale of 1 (very important) to 4 (null). We reverse the scale into 1 (null) and 4 (very important) for ease of understanding. We follow the approach of Kunapatarawong and Martinez-Ros (2014) when constructing environmental innovation. We first assign binary values for each objective. A response of 4 (very important) or 3 (important) receive a binary value of 1, where responses of 2 (some importance) and 1 (null) receive a binary value of 0. We then aggregate these answers and rescale the total score into 0 and 1, with firms having 0s across all four objectives as 0, and 1 otherwise.

From the data, we can see that firms are increasingly paying more attention to environmental innovation, with year 2010 showing higher average of importance paid to all environmental innovation objectives than 2008. On average, firms pay more importance on decreasing environmental impact and to comply with environmental and health regulations than on reducing material and energy usage per unit of production input.

Figure 4 illustrates the means of the degree of importance paid to each environmental objective when firms innovate by size and industry. On average, dirty industries and larger firms are more concerned with environmental innovation than clean industries or smaller firms. In PITEC, the industry is classified according to the Spanish National Activities Classification, CNAE2009. We distinguish dirty from clean industries based on not only the pollution level but also toxins as according to the latest Toxic Release Inventory (TRI)'s annual report of 2011 and the US Environmental Protection Agency (EPA). See Appendix 1 for further detail. We perform both t-test and Wilcoxo-Mann-Whitney test (not reported here) to test for the mean differences among these groups: manufacturing versus service industry, SMEs versus large firms, and dirty versus clean industries. Both tests are used as the use of t-test of difference on Likert scale can be highly criticized due to the nature of Likert scale that is not continuous. The results from both tests confirm that there are differences among these groups.

FIGURE 4
Innovation objectives by size and industry



Unfortunately, though PITEC incorporates the questions asking about percentage of environmental R&D, the data is not available. Moreover, as PITEC is not specifically designed to investigate environmental innovation per se. Our proxy could thus be criticized. To mitigate potential problems and to provide robustness of our analyses, we employ different specifications for our environmental innovation measure.

Control variables

Dummy variables, valuing 1 if the firm is a listed firm, private firm or institution, are included to control for firm characteristic. We also control for public financing in the form of subsidies. Almost 50% of Spanish firms receive some form of public support for R&D activities (INE, 201, 2011). We can thus expect that public financing may influence employment growth. We also control for wages as a proxy for the demand situation in the industry (Lachemaier & Rottmann, 2011). As the information on firm wages is not available, our next best approximation available is the average industry wage within a 2-digit National Classification of Economic Activities 2009 (CNAE2009). We obtain the information from INE's annual wage structure survey that reports the average annual earnings per worker per industry. As well, we control for market characteristic by including sales growth per industry. The information on prices is unavailable at firm level. To deal as best we can, we deflate growth in nominal sales with consumer price index as reported by INE. Different industries are subject to different market and economic contexts (Lachenmaier & Rottman, 2011). We can expect that this results in the differences in workers' structure and demand among industries. We include forty-two industry dummies as according to CNAE2009.

Results

Table 2 reports correlation coefficients. The untransformed value for employment averages 282 employees, with the maximum value of 38,619 employees. Examination of the correlations indicates that organization's environmental innovation is positively related with firm's employment. Specifically, green innovation is correlated significantly with firms having received subsidies from autonomous community and at the national level (r = 0.08, p < .05; r = 0.10, p < .05). As well, firms having received national-level subsidies (r = 0.12, p < .05) or subsidies from the European Union (r = 0.04, p < .05) correlate positively with employment. Average wage by industry also correlates positively with employment (r = 0.13, p < .05). The correlations indicate low probability of multicollinearity problem. Nonetheless, we further verify using Collin command in Stata. The variance inflation factors (VIFs) are in the range of 1-2.29 with the mean of 1.37, indicating no evidence of multicollinearity.

TABLE 2
Correlation Coefficients

	1	2	3	4	5	6	7	8	9	10
1. Employment	1									
2. Green innovation	0.11*	1								
3. Listed firms	0.15*	-0.04*	1							
4. Private firms	-0.08*	0.01	-0.72*	1						
5. Institutes	-0.04*	0.03*	-0.02	-0.67*	1					
6. Autonomous community subsidies	-0.01	0.08*	0.03*	-0.14*	0.17*	1				
7. National subsidies	0.12*	0.10*	0.01	-0.10*	0.13*	0.27*	1			
8. EU subsidies	0.04*	0.02	0.10*	-0.25*	0.25*	0.24*	0.26*	1		
9. Industry wage	0.13*	0.01	0.10*	-0.02	-0.08*	-0.03*	-0.03*	-0.04*	1	
10. Industry sales growth (deflated)	-0.01	0.02	-0.01	0.01	0.01	-0.01	0.02	0.03	-0.01	1
Mean	4.10	0.71	0.03	0.95	0.02	0.28	0.30	0.07	24751.59	0.03
s.d.	1.55	0.45	0.15	0.21	0.14	0.45	0.46	0.26	3971.96	0.66
Minimum	0	0	0	0	0	0	0	0	14629.55	-1.02
Maximum	10.56	1	1	1	1	1	1	1	48803.35	29.18

*$p < .05$

Table 3 reports results for hypotheses 1-2. Column (I) reports the results of the full model on the effect of environmental innovation in 2010 on employment in 2011. Column (II) reports the results with the interaction effect. The results support hypothesis 1. We find the increase of employment for environmental innovators and the effect is stronger for firms in dirty industries. The signs of most of the control variables are as expected. Listed firms are positively related with employment while private firms are negatively related. The relationship between employment and firms that have received subsidies from the Spanish government (national level) and the EU in the previous two years are positive. For manufacturing industry, firms in food, beverage and tobacco, paper and graphic arts, rubber and plastic products, metallurgy, motor vehicles experience an increase in employment. For service industry, the industries that create jobs are construction, wholesale and retail, transportation and warehousing.

In Column (III) of Table 3, we distinguish between voluntary and compliance-driven environmental innovation, testing hypothesis 2. We aggregate the answers for (1) reducing material; (2) reducing energy; and (3) lower environmental impact together and rescale the total score into 0s and 1s. We then use this score as a proxy for environmental innovation of voluntary type as these actions are completely voluntary. For compliance-driven environmental innovation, we use the same method to rescale a Likert scale of 1-4 (null to very important) into binary values. Firms reporting that they innovate in order to comply with environmental requirements receive a value of 1, and 0 otherwise. For Column (III), we perform the test on the equality of the two coefficients. The results show that the two coefficients are the same. Hypothesis 2 is not supported.

TABLE 3
Regression results for environmental innovation

	(I) Full model: 2011	(II) Full model: 2011	(III) Voluntary vs compliance driven	(IV) Full model: 2009	(V) Positive change in green innovation
Environmental innovation	0.2400**	0.1950**		0 .1388**	
Dirty industry		0.1768**			
Green innovation*dirty		0.2093**			
Voluntary			0.2056**		
Compliance			0.1129*		
Change in green innovation					0.1696**
Constant	1.2032	2.2795**	1.1494	1.5768	1.0681
Controls:					
Listed	0.8543**	1.7656**	0.8649**	0 .0451	0.8325**
Private	-0.3461*	0.3191*	-0.3339*	-0.6402**	-0.3589*
Autonomous community subsidies	-0.0298**	-0.1385**	-0.0363	-0.2024**	-0.0149
National subsidies	0.5565**	0.4279**	0.5521**	0.4687**	0.5741**
EU subsidies	0.3138**	0.1611	0.3087**	0.5741**	0.3071**
Industry wage	0.0001*	0.0001**	0.0001*	0.0001*	0.0001*
Industry sales growth (deflated)	0.0124	-0.0238	0.0131	-0.0187*	0 .0172

Industry	Yes		Yes	Yes	Yes
N	5,137	5,137	5,137	5,137	5,137
R^2	21.59%	7.62%	21.84%	21.43%	21.38%
F	25.87**	35.32**	25.73**	25.18**	25.67**
*$p < .05$, **$p < .01$					

We report additional results in Column (IV) and (V) of Table 3. Column (IV) investigates the impact of environmental innovation in 2008 on employment in 2009. Employment is consistently higher for environmental innovators than for non-environmental innovators in the period leading to the Spanish crisis. In Column (V), firms that report an increase or a constant degree of importance paid to environmental innovation from one period to another receive a value of 1, and 0 if firms report a decrease in the degree of importance. Instead of regressing employment in 2011 on environmental innovation in 2010, we regress employment in 2011 on the change in environmental innovation from 2006-2008 to 2008-2010. We are aware that firms' priorities might have changed over the years. It is one of the limitations of our model that we cannot address. The results show a positive and significant relationship between employment and firms that report an increase or at least no change in the degree of importance paid to environmental innovation.

Discussion

Our results show that environmental innovators increase employment more than non-environmental innovators and non-innovators, and the effect is stronger for dirty industries. Our results are consistent with previous studies (Horbach & Rennings, 2013; Rennings et al., 2004; Rennings & Zwick, 2002). It appears that market do reward firm's environmentally innovative behavior because environmental innovators seem to be better off than non-innovators or non-environmental-innovators if we judge it from the fact that these firms still expand and employ more people both before and during the crisis. Subsequently, such rewarding behavior goes back to the society in the form of increased employment.

Merely because of the fact that the firm is in a dirty industry, the idea for new environmental innovation may come more from firm's internal sensitive to environmental issues rather than from having to comply with regulations or customers' requirements in terms of environmental issues. This would make their strategies more proactive rather than reactive. Prior literature shows that proactive environmental strategies are associated with improved firm's financial performance (Klassen & McLaughlin, 1996; Klassen & Whybark, 1999; Russo & Fouts, 1997) and competitive advantage (Aragón-Correa & Sharma, 2003). Likewise, for whichever reasons, top management may be more personally committed to sustainability, thus helping to drive environmental innovation that may have substantial environmental impact and stronger economic impact. Similarly, these firms may have a clearer and a better specified plan to deal with environmental innovation than say cleaner industries that are less subject to scrutiny and environmental regulations. These plans are likely to be put in place as a result of a thorough study of the product-life cycle analysis, resulting in many advantages such as optimization in energy costs and packaging, logistical advantages, reduction in material consumption, lower risks for health and safety of consumers as well as employees, etc. After all, green markets do exist and is likely to get much bigger in the future (Dangelico & Pujari, 2010; OECD, 2013). In sum, these are likely to result in an increase in firm performance and consequently labor input.

From a macroeconomic background in Spain, the time period from 2007-2011 was characterized by an economic crisis and high unemployment rate that was at 21.6% in 2011, the highest in EU-27 (INE, 2012). Our results hence have serious policy implications. More efforts to promote and provide incentives towards green growth at national- and autonomous community-level should be made in order to improve the overall Spanish framework regarding environmental technological competencies and consequences. After all, Spain aims to use environmental innovation to help boost economic growth (Barranco, 2013). Our results provide valuable evidence that Spain is heading in the right direction in terms of using green growth to boost growth.

Further, our study reveals that no matter firms develop environmental innovation merely in response to environmental regulations or they voluntarily develop environmental innovation, these environmental innovators create jobs. Though both cost-savings from managing resources efficiently and cost-increase from having to comply with regulations might lead to a decrease in employment, it seems environmental regulations can still become an opportunity for new business creation (Dangelico & Pujari, 2010), thus, job creation. Our results are consistent with Porter Hypothesis that environmental regulations provide firms with opportunities for improved efficiency; therefore, an increase in employment. It seems 'the end justifies the means'.

Care should be taken when interpreting this result. A myriad of environmental instruments on environmental innovation exist. With our proxy for compliance-driven environmental innovation, we cannot make distinction between command and control type or market-based regulations. End-of-the pipe technologies fall under the first category. Tradable emissions, environmental certificates or environmental taxes fall under the latter category (van Leeuwen & Mohnen, 2013). We cannot conclude that command and control type regulation is more effective than market-based regulation or vice versa. In addition, prior literature asserts that what determines the impact on the change in employment depends on the level of stringency and concreteness of environmental measures (Rennings et al., 2004). We cannot tell at which level of policy stringency triggers positive impact on employment through environmental technology developments.

Empirical work on environmental innovation-employment relationship can be influenced by a wealth of different factors. This work presents us with limitations.

First, PITEC dataset is not built specifically to assess environmental innovation. It limits our approach to measuring environmental innovation from innovation objectives with environmental concerns. We cannot tell the actual outputs or economic values from innovation objectives. We also cannot determine when or whether the objectives get turned into actual environmental-friendly technologies. Too, responses to questionnaires can by seriously biased as respondents tend to present a socially responsible image of themselves or their firms (Berrone et al., 2013).

Second, our measure of environmental innovation is an all-encompassing construct. We could only distinguish voluntary from compliance-driven environmental innovation. We could not decompose our measure into more types of environmental innovation that exist.

Third, we only provide firm-level analysis on employment and environmental innovation. To draw implications for aggregate level from this study, caveats should be taken into consideration.

Fourth, we consider only the total level of employment. We do not consider its composition in terms of skills or types of worker. The demand for skilled labor might be higher than for unskilled labor, or even a decrease in a demand for unskilled labor in some cases. Our study could not address the possibility that environmental innovators lead to more or less employment of skilled or unskilled workers.

Future research could use other measures to help improve the analysis on the topic. Costs and benefits of environmental innovation vary and are probably correlated with employment changes incurred by them. The use of other measures of environmental innovation that incorporate costs and benefits factor into the measure would help to improve the analysis. An alternative measure can be sales or revenue growth due to environmental innovations. Another option can be environmental patent or the number of new environmental products or processes (Kemp & Pearson, 2007). In this manner, we would be able to estimate gross effect of environmental output on employment.

In addition, as we cannot supplement our analysis with external data due to confidentiality nature of PITEC dataset, we think it is important for future research to include information on environmental-related performance. For instance, the analysis could be improved by including a control for firms' environmental performance such as whether or not a firm is ISO14001 certified, EMAS registered, or the like. Firm's previous environmental performance or previous environmental crises might be a factor causing firms to be more or less attractive among employees. Prior literature shows that firms' corporate social performance (which includes environmental performance) is positively related to their reputations and attractiveness as employers (Turban & Greening, 1997).

The effect of environmental innovation on employment at the aggregate level is of great value for future research. As we do not consider why and how firms innovate and grow, future research on firm-level employment growth should be complemented with other firms' economic or regulatory situations or other organizational factors. For instance, the size of environmental innovation, the information on government policies influencing employment, bursts in capacity utilization and labor, or temporary organizational problems would help to improve the model (Harrison et al., 2008). Moreover, autonomous regions in Spain present considerable differences in their physical, social and economic conditions as well as in terms of environmental policies and public financing received (INE, 2012; OECD, 2004). A regional-level control should be taken into consideration. For future research at the aggregate level, as we do not observe the effect of firm entering or exiting in our sample, a full analysis incorporating entry, exit and competition between rival firms would be fruitful. Firm entry and exit are an important source impacting growth or decline in employment (Harrison et al., 2008).

Lastly, a great contribution that future research should attempt is to not only distinguish between green product and process innovation, but also to further subdivide. It would also be interesting to conduct comparable studies, especially comparing countries that are considered to be in an environmental innovation-rich context versus countries that are less developed in terms of being green. A comparable study on entirely different institutional, economical and environmental contexts would help to explain whether or not the structural effects play a large role in influencing firms to go 'green' or even more importantly to be sustainable. Such comparable study has both direct policy implications as well as indirect benefits on green consumerism and sustainable literature.

Conclusion

We can establish 'the existence' of a positive relation between variables proxying environmental innovation and employment at firm-level. For a variety of reasons, relatively little work has been completed, both theoretically and empirically, on the changes in employment as a result of environmental innovation. Results at the firm-level are still ambiguous and views about the impacts are highly controversial (Rennings et al., 2004). The novelty of our study is that, to our knowledge, this is one of the very few statistical studies assessing the impact of environmental innovation on employment at the firm-level.

We base our study on PITEC dataset. The increasing relevance of environmental issues for the Spanish economy, its unemployment problem and the uniqueness of the Spanish innovation structure (De Marchi, 2012) make it a proper and interesting context to investigate environmental innovation dynamics. Our estimation results on more than five thousand firms show the increase of employment for environmental innovators, as compared to non-environmental innovators and non-innovators, both before and during the Spanish crisis that started in 2009. The increase in employment is higher for dirty industries. Our results show that no matter firms introduce environmental innovation voluntarily or merely to comply with regulations, they create jobs. In addition, our results show a positive and significant relationship between employment and firms that report an increase or at least no change in the degree of importance paid to environmental innovation. This study hopes to provide not only a clearer understanding of the impact of environmental innovation on employment at firm-level, but also policy implications on the Spanish economy where it has and is still experiencing a severe unemployment problem.

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Appendix 1: Industry classification: Dirty and clean industries

Dirty	**Clean**
Agriculture, livestock, fishing	Garment
Extractive industries	Other machinery
Food, beverage and tobacco	Other transport equipment
Textile	Miscellaneous manufacturing
Leather	Machinery repair
Wood	Commerce
Pulp and paper	Warehousing
Printing	Accommodation
Chemicals	Telecommunication
Plastics	Information technology
Pharmacy	Software development
Non-metallic mineral products	Finance and insurance
Metallurgy	Real estates
Metal	R&D
Computers and electronics	Other activities
Electronics	Administrative services
Cars	Education
Shipbuilding	Social services
Airplanes	Arts, recreations and entertainment
Furniture	Other services
Energy and water	
Waste management	
Construction	