The effects of green regions on local firms' innovation

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Abstract
Technological innovation, which is one of the main engines of economic growth, is essential to meet the so-called *green growth*, i.e. to achieve simultaneously economic, environmental and social goals. Indeed, many studies have suggested that environmental innovation could spur overall innovation of firms, industries, and countries. Therefore, an increased commitment by public and private actors in environmental issues could be an important driver of innovation. However, this issue has not been investigated by taking into account the geographical context in which the innovative firms operate. Therefore, our paper seeks to investigate whether "green regions" (i.e. where public and private actors are engaged in reducing the environmental impact of economic activities) stimulate the capacity of local firms to be innovative. Using data on Spanish manufacturing firms and regions, we find that environmental technologies (especially in green energy), environmental expenditures (especially investments), and environmental management at the level of regions positively affect the probability of local firms of innovating.

Keywords: green innovations, environment, region, manufacturing, environmental management

1 Introduction

It is widely recognized that economic growth cannot be pursued by ignoring the environmental and social concerns. This concept is at the basis of the so-called *green growth*, which is the idea that economic, environmental and social goals could be achieved simultaneously. Technological innovation, which is the main engine of economic growth, is essential to meet a green growth. Innovation makes existing industries more environmental sustainable while at the same time promotes new industries and a diversified economy (OECD, 2011a). Exiting research has devoted a lot of attention on the determinants of those innovations that positively impact the environment (Brunnermeier and Cohen, 2003; Del Río González, 2009; Horbach, 2008; Horbach et al., 2012; Johnstone et al., 2012; Wagner, 2007). Most of these determinants are very similar to those for general innovation, although the political framework plays a crucial role in environment innovation (Porter and van der Linde, 1995).

This stream of literature also acknowledges that environmental innovation could spur overall innovation capacity of firms, industries, and countries, enhancing their competitiveness (Rennings and Rammer, 2011; Rexhäuser and Rammer, 2014; Yang et al., 2012). Therefore, this literature suggests that being more concerned of the environmental impact of the economic activities (e.g. through ad-hoc government policies, new technological trajectories undertaken by firms, new types of environmentally-friendly products introduced by firms, etc) could boost competitiveness through innovation at the country, industry or firm-level.

Despite innovation occurs at the firm-level, external factors of the geographical context in which the firm sits could affect the innovation capacity of firms. Studies that have tried to reconcile the micro-level and the aggregate-level suggest that some regional factors could affect firm innovation, such as R&D, technology transfer and networking, availability of highly skilled labour and proximity to suppliers, the quality of the innovation system, and agglomeration externalities (Czarnitzki and Hottenrott, 2009; Love and Roper, 2001; Naz et al., 2015; Srholec, 2010). However, among these regional factors, whether being a "green region" (i.e. where public and private actors are engaged in reducing the environmental impact of economic activities) is a determinant for local firms' innovation has been neglected. On the specific literature of the determinants of environmental innovation, few firm-level studies introduce spatial elements (Antonioli et al., 2016; Cainelli et al., 2015, 2012; Ghisetti and Quatraro, 2013; Horbach, 2014), but they do not investigate the link to overall innovation, which has powerful implication to foster the green growth.

We intend to fill this gap by investigating whether certain characteristics of being a green region stimulate the capacity of local firms to be innovative. We take into account both traditional

inputs to regional knowledge production (Acs et al., 2002) and specific indicators of green regions (i.e. identified according to the production of environmental technologies, the expenditures in environmental protection by the industrial sector, and the environmental management tools adopted by local organizations), while also taking into account the firm-level determinants of innovation output.

The paper is organized as follows. Section 2 presents the theoretical background and our expectations. Section 3 explains the methodology and the data. Results are shown in Section 4, and finally conclusions are drawn in Section 5.

2 Theoretical background and propositions

Firms' innovation is determined by internal and external factors. Internal factors may concern technological competences, human resources, organisational capabilities, size and market structure (Vega-Jurado et al., 2009). External factors, relative to the geographical context in which the firm sits, may concern R&D expenditures, human capital, agglomeration economies and industrial specialization (Jaffe et al., 1993). A long tradition in the geography of innovation has recognized the importance of the context. Firms do not carry out innovation activities in isolation, but their innovative output is the result of interactions with a set of actors, such as users and suppliers, research centres and universities, and financial institutions that are localised nearby (Asheim and Coenen, 2005). The interaction with these actors is often voluntary, as firms may actively engage in various forms of collaboration. In addition, being placed in a certain location may have the advantages of being exposed also to involuntary knowledge spillovers that may come from the mobility of workers among local firms, participation at fairs or business associations, or simply by informal contacts facilitated by proximity.

The importance of the contextual factors has been sought at the aggregate level of regions or other spatial units (Acs et al., 2002; Griliches, 1990; Jaffe, 1989). An alternative approach has tried to reconcile the micro-level (at which the process of generating innovation occurs) and the aggregate level. Part of these studies showed that internal determinants are important for the firm's ability to innovate while regional factors are negligible, suggesting that the firm heterogeneity plays the major role among the determinants of innovation (Beugelsdijk, 2007; Smit et al., 2015; Sternberg and Arndt, 2001; Vega-Jurado et al., 2008). Instead, other recent studies, although recognizing that firm's characteristics are important, conclude that location matters a lot too, like for example R&D, technology transfer and networking, availability of highly skilled labour and proximity to suppliers, the quality of the regional innovation system and some social characteristics,

and agglomeration externalities (Czarnitzki and Hottenrott, 2009; Love and Roper, 2001; Naz et al., 2015; Srholec, 2010).

One aspect that has been neglected in the studies connecting the micro and aggregate level is the possibility that different market and policy conditions may change over time, so that regional technological trajectories and economic specialisation that were successful in the past might not be appropriate under the new changing conditions (Boschma, 2005) or that the changing conditions could provide new stimuli for the economy. In this sense, the recent emphasis on the green growth could be seen as a major change that could provide new opportunities for firms to expand existing markets or explore new ones, adopt products/processes that are more efficient to produce, gain more trust from consumers for adopting green strategies, and so on. The key to exploit this transformation is innovation, whether in the form of technological innovation or the introduction of new products or process, or even the organizational innovation (OECD, 2011a).

Different factors related to environmental issues could stimulate the innovation capacities of firms in a certain region. The starting point is that firms or other local innovative actors may introduce innovations related to meeting environmental goals and economic opportunities to grow. Differently than any other innovation, these changes are very likely to be induced by environmental policies (Porter and Van der Linde 1995) or an increased awareness towards environmental issues to anticipate future policies and economic opportunities. Then, once such environmental innovation has been introduced, it is likely to generate knowledge spillovers through the traditional channels identified by the literature on the geography of innovation (Breschi and Lissoni, 2001): backward and forward linkages, labour mobility, demonstration effects, industry-university linkages, R&D alliances, informal sharing of know-how and communications at conferences and fairs (e.g. Bode, 2004; Perkmann et al., 2013; Rodríguez-Pose and Crescenzi, 2008; Rondé and Hussler, 2005). Therefore, we expect that innovation in the environmental domain observed at the regional level could trigger specific environmental innovation or other types of innovation in local firms.

The sources of innovation related to environmental issues could be of different types. We consider three of them: environmental technologies, environmental protection expenditures, and environmental management.

First of all, new appealing opportunities (e.g. developing energy-saving technologies to reduce production costs), or the rising demand of certain goods (e.g. electronic devices that consume less, or new green products such as photovoltaic panels) could promote new environmental technologies. Indeed, green technology development in the form of patents seem to be growing faster than total patents during the 2000s, especially in fields such as renewable energy, electric and hybrid vehicles, energy efficiency in building and lighting (OECD, 2011a). This suggests that firms may see market

opportunities in environmental technologies, along with the need to comply with increasing strictly environmental regulation. Accordingly, firms or organizations involved in developing environmental technologies could stimulate innovation in other firms in their network of partners or in the proximity; such innovation could be related to environmental technologies, or being more generally about new technologies, processes or products. For example, automotive firms that have decided to develop electric cars to meet the future demand and more stringent regulation for green transportation, could design smaller and lighter vehicles, requiring their local suppliers to come up with new innovative solutions. Hence, we posit that:

Environmental technologies positively affect the innovativeness of local firms.

A second source of innovation related to environmental issues could come from the expenditures that firms sustain to protect the environment, either because of a more stringent regulation or a specific choice of the firm. Most of the policies to foster green growth are formulated at the international and national level, such as setting technological standard, or feed-in tariff for electricity generated by renewable sources (OECD 2011). However, the regions and local authorities transform policies decided at the higher level in concrete actions and they may be already pioneering, initiating and practising some of the recommendations (EU 2015), such as the adoption of environmental-friendly equipment, a public transportation system in line with a sustainable mobility, the introduction of tax credits to adopt energy efficiency standards for manufactured goods. These policies could affect local markets and technological specialization. Therefore, specific local policy and market conditions could provide a favourable context to exploit the opportunities of a green growth.

Even the simply fulfilment of regulations and standards could spur environmental innovation (Horbach, 2008) and efficiency (van der Vlist et al., 2007). If the environmental regulation induces innovation in resource efficiency and reduction of pollution and waste, this could positively affect financial performance (Ghisetti and Rennings, 2014; Rexhäuser and Rammer, 2014). Also in the case of innovation not directly related to regulation requirements, innovation in resource-efficiency could affect financial performance (Rennings and Rammer, 2011). Therefore, we expect that regions where environmental protection expenditures of the private sectors are high, are generating innovation and, through the channels described above, knowledge spillovers. This eventually will increase the probability of local firms to introduce innovation. Hence, we posit that:

Environmental protection expenditures positively affect the innovativeness of local firms.

A third source related to environmental issues is the introduction of environmental management tools. Firms and organizations that are willing to be more resource-efficient and give an environmentally-friendly image to the outside could also make environmental organizational changes. There are voluntary programmes that help to monitor the organization in order to identify which areas to intervene to accomplish certain environmental goals (e.g. reducing emissions, use less energy, use alternative raw materials, etc). Such programmes have been found to positively impact environmental innovation and economic performance (Rennings et al., 2006). Therefore, similarly to the mechanism of innovation-inducement and knowledge spillovers we have highlighted above, we expect that such innovation could be diffused to the entire regions, increasing the probability of other firms to be engaged in innovation. Hence, we posit that:

Environmental management tools positively affect the innovativeness of local firms.

3 Methodology and data

3.1 Methodology

Our model of interest is:

$$Y_{irt} = a + \boldsymbol{X}_{irt}\gamma + \boldsymbol{Z}_{rt}\beta + \varepsilon_{irt}$$

where Y_{irt} is the dependent variable, a proxy of innovation, for firm *i* in region *r* at time *t*. $\boldsymbol{X}_{irt}$ are characteristics of the firm and $\boldsymbol{Z}_{rt}$ are characteristics of the region where the firm is located. ε_{irt} is an error term. Following our theoretical discussion, it is reasonable to assume that firms located in the same region are exposed to the same institutional and economic background. This correlation within regions is often modelled assuming that the residual ε_{irt} has a group structure (Angrist and Pischke, 2009, chap. 8):

$$\varepsilon_{irt} = v_{rt} + \eta_{irt}$$

where v_{rt} is a random component specific to region *r*, and η_{irt} is a mean-zero firm-level component. The within-group correlation when using micro-data with regional-level covariates can cause a bias of the standard errors, leading to overestimate the importance of regional characteristics on firm-level innovation (Moulton, 1990, 1986).

To tackle this problem, we employ a "two-stage" procedure (Angrist and Pischke, 2009, chap. 8), widely applied in empirical studies on the relationship between individual wages and regional or provincial unemployment rate (Ammermuller et al., 2010; Peng and Kang, 2016).

In the first step, firm innovation is regressed on micro-characteristics and region-by-year fixed effects that are proxies for regional-level factors:

$$Y_{irt} = a + \boldsymbol{X}_{irt}\gamma + \boldsymbol{D}_{rt}\mu + \eta_{irt}$$

The group effects μ are coefficients on a full set of region-by-year dummies $\boldsymbol{D}$. The estimated $\hat{\mu}$ are group means adjusted for the effect of the firm-level variables $\boldsymbol{X}$. The random-effects logit estimator is used in this first step.

In the second step, we regress the estimated group effects on group-level variables (regions, in our case):

$$\widehat{\mu_{rt}} = b + \boldsymbol{Z}_{rt}\beta + v_{rt}$$

The fixed-effects estimator is used in this second step. The firm level estimation is carried out with a random-effects model whereas for the regional one we use fixed-effects. This is so because we follow the distinction between the fixed and the random effects models as a distinction between a conditional and an unconditional inference (Baltagi, 1995). When the individual effects are fixed, our inference is conditioned to the individuals (or cross-section observations) of our sample. The conditional inference is probably accurate if the individuals for which we have data are not a random sample extracted from a higher population but the whole population. This is the case in the regional regression in the second step. On the contrary, if the individuals are a random sample from a higher population, and we are interested in obtaining inference for the whole population, then the unconditional inference that is implicit in the error components approximation, that is, the random-effects model, seems more accurate. This is the case in the firm level regression in the first step.

3.2 Data

In the first step, we use micro-data that are drawn from the Survey on Business Strategies (ESEE), a panel of manufacturing firms located in Spain. Data are collected by the Ministry of Industry and Energy in collaboration with the SEPI Foundation. About 1800 firms have been surveyed since 1990 each year, using a questionnaire that includes information on a wide range of topics (innovative activities, financial data, market and product characteristics, among others). It covers firms with 10 or more employees. All firms with more than 200 employees are included, while firms employing between 10 and 200 workers are representative of the population of reference. Our final sample entails 5304 firms in the years 2004-2013.

The dependent variable used in the first step is binary, indicating whether the firm has introduced an innovation in the given fiscal year or not. In particular, we use two different dependent variables: product innovation (*PROD*) and process innovation (*PROC*). Table 1 presents

the number and percentage of firms introducing innovation in selected years, showing that process innovation seems to concern a higher number of firms than product innovation.

[TABLE 1 here]

We control for a set of firm-level characteristics, as suggested by the literature on the determinants of innovation that use survey-data. We control for firm size measured as the number of employees (*size*) and we also introduce its squared term (*size2*) to take into account nonlinearities (Robin and Schubert, 2013), both transformed in natural logarithms. We introduce the share of internal R&D expenditures on turnover (*in-house R&D intensity*) as a proxy for a firm's absorptive capacity (Triguero and Córcoles, 2013). In addition, we use a set of dummies accounting for whether the firm conducted internal R&D activities continuously (*permanent R&D*) (Raymond et al., 2010), whether it has a *foreign* ownership of more than 50% (Nieto and Santamaría, 2010; Triguero and Córcoles, 2013), whether the firm exports or not (*export*) (Beneito, 2003) and whether it has access to R&D funded by public government (*public R&D funding*). We also account for the dynamism of the most important market in which the firm operates (i.e. *expansive market*, *stable market*, and - as benchmark category – market in decline, as declared by the firm itself) (Triguero and Córcoles, 2013). In line with the literature that recognizes the importance of external sources of knowledge, we introduce a binary indicator for R&D *cooperation* (Tether, 2002) in case the firm declares having technological cooperation agreements with other firms or institutions. Finally, we expect firms operating in high technology industries to be more innovative than their counterparts in low technology industries. The variable *high-tech sectors* is a dummy that takes the value 1 if the firm belongs to a high technology industry (Valle et al., 2015)[1]. All the covariates are 1-year lagged, except high-tech sectors.

For the second step, we collect data on the 17 Spanish NUTS2 regions for the period 2004-2013 from different sources. As discussed in the previous section, the dependent variable is the estimated group effects obtained from the first step.

[1] Following Valle et al. (2015) we adapt the OECD classification of manufacturing industries (OECD, 2011b) to the ESEE. Industries 9 (chemical and pharmaceutical products), 14 (agricultural and industrial machinery), 15 (computer, electronic and optical products), 16 (electrical machinery and equipment), and 17 (motor vehicles) are classified as high technology industries (corresponding to OECD high and medium-high technology industries). The remaining industries are considered low technology industries (corresponding to OECD medium-low and low technology industries): meat products, food and tobacco, beverages, textiles and wearing apparel, leather and footwear, wood, paper, graphic arts, rubber and plastic products, ferrous and non-ferrous metals, metal products, furniture, miscellaneous manufacturing. Differently than Valle et al. (2015), the industry "other transport materials" (which includes aircraft and spacecraft, railroad equipment and transport equipment, n.e.c., and building and repairing of ships and boats) has been considered as low-tech industry.

As control variables in the second step, we introduce a set of determinants of regional innovation, as in the tradition of the regional knowledge production function (Jaffe 1986, 1989). Data are drawn from Eurostat. We introduce *business R&D per GDP* and *public R&D per GDP* to control for the role of knowledge inputs of the private and public (government and high education) sectors, respectively (Acs et al., 2002). The industrial specialization is accounted for by the employment share in manufacturing (*manufacturing specialization*) (Marrocu et al., 2013). We also control for different regional size (inhabitants per square kilometre) and agglomeration economies with the population density (*pop. density*) (Miguélez et al., 2011) and its squared term for non-linearity (*pop. density 2*).

Indeed, the literature using the construct of a regional KPF to assess the relationship between technological inputs (such as R&D investments) and innovation outputs was first used in the seminal studies of Griliches (1979) and Hausman et al. (1984) at the firm level, and subsequently extended by Jaffe (1986, 1989) to the regional level. This approach believes that knowledge – especially that of tacit nature – is difficult to appropriate in its totality by its producer and therefore may spill over to third parties, on the one hand; and on the other, on the evidence that knowledge diffusive patterns are subjected to strong spatial decays (Jaffe et al. 1993). These two ideas have produced a prosperous literature declaring that, by being co-located in the same physical space, agents are subjected to a constant amount of information flows and knowledge transfers that take place unceasingly in both organized and accidental meetings (Bathelt et al. 2004).

Some criticisms to this logic stemmed since the path from R&D efforts to innovation is not always straightforward. Rodriguez-Pose (1999), among others, signal that different social and institutional local conditions may lead to important geographical differences in the returns to innovation. Indeed, countries and regions differ in their socioeconomic composition, which may justify a substantial part of their heterogeneity in innovation performance. As a consequence, certain issues related to the regional environmental concerns may influence regional innovation rates.

As a consequence, our regression in this second step includes several key independent variables used as a proxy for being a “green region”: environmental technologies, environmental protection expenditures, and environmental management, as discussed in section 2.

For environmental technologies, we use patent applications from the OECD REGPAT database and classify them by the IPC Green Inventory[2] of the World Intellectual Property Organization (WIPO). This classification identifies IPC classes that entail technologies that could significantly improve environmental performance, such as protecting the environment, using resources and treat

[2] http://www.wipo.int/classifications/ipc/en/est/

wastes in a more sustainable way than traditional technologies. In comparison to other classification such as the Indicator of Environmental Technology (ENV-Tech Indicator) by the OECD, WIPO classification has a broader scope (Marin, 2014). We use EPO designated PCT applications that are 'regionalized' by allocating inventor and applicant addresses to each region (Maraut et al., 2008). We take the fractional count of PCT applications aggregated by the region *r* of residence of the inventor, so that when a patent application has multiple inventors resident in different regions, we assign a share to each region (for example, a patent with an inventor resident in Madrid and another resident in Barcelona is equally assign to the Comunidad de Madrid and to Catalonia with a 0.5 share). We then selected the patents whose IPC codes match the IPC Green Inventory to compute the share of green patents on total patents (*green patents*). We also distinguish green patents by the seven topics of the IPC Green Inventory and group them in three variables (which are calculated as shares on total patents): *energy patents* (i.e. alternative energy production, energy conservation, nuclear power generation), *transportation patents*, and *other green patents* (i.e. waste management, agriculture and forestry, administrative, regulatory, or design aspects). Since for regions with smaller total patents these shares could overrepresent the importance of green patents, we also calculate a Revealed Technological Advantage (RTA) index of different green-technology groups relative to all patents of the sample:

$$RTA_{rj} = \frac{P_{rj}/\sum_j P_r}{\sum_r P_{rj}/\sum_{rj} P_{rj}}$$

where P_{rj} is the number of patents in region *r* in group *j* (*j* = *energy patents*, *transportation patents*, *other green patents*, *non-green patents*). Thus, this index gives the share of patents in region *r* in group *j*, weighted by the share of patents in all regions in group *j* on all patents in the sample. To make this index between -1 and +1, we apply the following transformation:

$$adjRTA_{rj} = \frac{RTA_{rj} - 1}{RTA_{rj} + 1}$$

The value +1 represents the technological specialization of region *r* in technology group *j*, while the value -1 indicates no specialization.

For the indicators of environmental protection expenditures, we use the Survey on Industry Expenditure on Environmental Protection carried out by the Spanish national statistics institute (INE) annually since 2008. This survey reports the current expenses and investments on environmental protection made by establishments to avoid, reduce or eliminate the pollution resulting from their activities. The survey provides two main variables: current expenditures and investments. Current expenditures is defined as[3]

[3] See methodological note: http://www.ine.es/en/daco/daco42/ambiente/metoemin_en.pdf

"*those operating expenses […] whose main objective is the prevention, reduction, treatment or elimination of the pollution or any other degrading of the environment arising as a result of the activity of the establishment. It fundamentally comprises the following expenses:*

- *Payments to other companies for purchases of environmental protection services.*
- *Payments to the Public Administrations as fees (not including taxes or unrequited payments).*
- *Expenses associated with the equipment used (repairs, energy consumption and consumption of raw materials).*
- *Other expenses related to environmental protection, such as personnel employed in environmental protection activities, expenses on R&D activities related to the environment, expenses on personnel training, etc."*

Investments are defined as:

"the capital resources acquired to be used in the productive process for more than one year, purchases of capital goods or intangible assets carried out by the company during the reference year."

Examples of investments are: equipment and installations for reducing the emissions of atmospheric pollutants, for the prevention of wastewater, that generate less waste, for saving and reusing water, for reducing the consumption of raw materials and energy. For each of the two measures, we compute the ratio between environmental protection expenditures in the manufacturing sectors and GDP (*EEX* for current expenditures, and *EINV* for investments) in each region for the latest period for which data are available (i.e. 2008-2013). *EEX* indicates a cost sustained by the firms in order to maintain their environmental protection activities. This commitment could be due to a technological choice made by the firm (e.g. building smaller electronic devices requires more energy), to the natural resource endowments and industrial specialization of the region (e.g. to generate electricity, regions might rely on burning fossil fuels or they might use alternative sources such as wind, solar, or hydroelectric power, depending on the local availability) or to a specific environmental standard and regulation imposed by the government (national or local). Similarly to *EEX*, *EINV* indicates that the investment could be induced by external forces (e.g. availability of resources or environmental regulation), but also that it could be voluntary (e.g. the will to reduce the impact on the environment). However, differently than *EEX*, *EINV* indicates a long-term commitment to either prevent or clean-up pollution that require the introduction of equipment and installations that certainly are new to the firms. This aspect could stimulate other innovations in the firms, as the firms might discover cheaper or more effective production process, or even introduce new products that require less energy or raw materials whose idea has been inspired by the initial investment. In their seminal work on how environmental regulation could spur innovation in firms, Porter and van der Linde (1995) report

several anecdotes on how the compliance to a more stringent regulation has led to new processes or products that the firms are willing to develop beyond the regulation' requirements. At the aggregated level, innovation resulting from high environmental investments could spill over to other firms in the regions.

For the indicator of environmental management, we collect information on the adoption of the EU eco-management and audit scheme (EMAS) by organizations (enterprises or institutions) in Spanish regions. This information is freely available online from the EMAS register[4]. Organizations adhere voluntarily to this scheme to evaluate, report, and improve their environmental performance. The introduction of environmental management tools has been found positively correlated to environmental innovation at the firm-level (Horbach, 2008; Wagner, 2007). At the aggregated level, this innovation could spill over to other firms in the regions. Due to the high variability in the number of new EMAS certifications each year, the variable *EMAS* is calculated as 2-year average to smooth peaks.

Control variables in the second step are 1-year lagged. The key independent variables related to environmental technologies are 2-year lagged, as it is required more time from the year of the patent application to the public availability and diffusion of its content. Similarly, *EEX* and *EINV* are 2-year lagged, as it might take a certain amount of time from the initial expenditures (forced or voluntary) to spur innovation and then knowledge spillovers to the entire region.

4 Results

We present the results for the second step. A correlation matrix with mean and standard deviation, and the estimates for the first step are given in Appendix A.1 and Appendix A.2, respectively. The correlation table with mean and standard deviation for the second step are in Appendix B.1.

Table 2 shows the estimations of the fixed-effect panel at regional-level, where the dependent variables are the estimated group effects of the first step, for product and process innovation separately. Model 1-8 presents the results for green patents and their different groups, taken as shares on total regional patents. *Green patents* (Models 1-2) are not statistically significant and neither any of their different groups, with the exception of *energy patents* which has a positive and statistically significant effect only on process innovation (Model 4, at $p < 0.10$). The results for green energy technologies are reinforced if we consider the adjusted RTA (Model 10, at $p < 0.01$). In addition, the specialization in green transportation patents (i.e. *RTA Transport. Patents*) turns out

[4] http://ec.europa.eu/environment/emas/register/

positive and marginally statistically significant for product innovation (Model 11, at $p < 0.10$). These results point out that a region more engaged in environmental technologies does not necessarily produce knowledge spillovers from which local firms could benefit. However, specific environmental technologies have this power. In particular, it seems that energy patents are particularly apt for this role. In this category, we find technologies that have the direct purpose to find alternative ways to produce energy than traditional fossil-based sources, as well as new methods of energy conservations. These are two key fields in which technology could help the green growth, namely by finding new environmental-sustainable energy sources and at the same time working on energy-efficiency. These are also fields that could spur further innovation more directly. For example, a firm that has patented a new system to fuel a certain phase of its production process by using solar energy is already introducing a process innovation; also, this could lead to further changes in the production process, perhaps not directly linked to the solar energy or not patentable but that constitute an innovation. Then, these new waves of innovation could cause further innovation along the value chain in the proximity of the firm, or simply become new knowledge that spill over through worker mobility or collaboration with other firms. It is not surprisingly that energy patents do not have an effect on product innovation, as energy is considered a production factor, so any improvement in this sense is more likely to affect the production process, rather than a final product, unless we consider firms operating in sectors producing final goods that incorporate these new technologies (e.g. producers of solar panels). Similarly to energy patents, it seems that also transportation patents are able to have a certain effect on innovation when the region has a comparative advantage in these technologies, although in this case on new products. In this category of technologies, we find all types of vehicles that use new sources of energy (e.g. electricity, hydrogen) or a combination of old and new sources (e.g. hybrid vehicles). Although these types of patents could regard entire new vehicles, most of the technologies are components, such as engines and braking systems. In this latter case, it is very likely that the introduction of new components stimulate innovation in related components (namely, in product innovation), to be produced by the same firm or by its network of suppliers, clients, competitors and collaborators in the vicinity.

With regard to the control variables, *business R&D per GDP* is consistently positive and statistically significant ($p < 0.01$) for all specifications for process innovation, while unimportant for product innovation. Within the regional knowledge production function framework, industrial R&D is found strongly correlated to patent output (O hUallachain and Leslie, 2007) and to innovation output (Acs et al., 2002). Probably, in our case the stronger link between business research and process innovation (and not product) could be due to the fact that a higher share of firms in our

sample carries out process innovation. *Public R&D per GDP* is consistently negative and marginally statistically significant ($p < 0.10$) for all specifications for product innovation (except in Model 1), while unimportant for process innovation. While the empirical evidence generally points out that university and government research are important determinant of firms' innovation (Acs et al., 1992), in our sample the regions with the highest public R&D intensity are not only the richest (such as Catalonia and Comunidad de Madrid) but also backward regions with smaller economies (such as Cantabria and Extremadura) in which the public R&D spending (although smaller in absolute number than other regions) drives upwards the R&D intensity because of a low denominator. Therefore, in these latter regions, despite the public expenditure in research constitutes a relatively high share of the economy, the expected knowledge spillovers to firms' innovation do not seem to materialize, or not yet. Hence, regions with high public R&D intensity are negatively correlated to the capacity of firms to introduce innovation. Such relation is particularly strong for product innovation, perhaps for the nature of our sample, where firms, if they do innovation, are more likely to carry out process innovation than product innovation. Therefore, the disadvantage of being in a region with a high weight of public research is particularly strong for the firms struggling to introduce new products. The remaining controls (*manufacturing specialization*, *pop. density*, and *pop. density 2*) are not statistically significant.

[TABLE 2 here]

Table 3 shows the estimations of the second step with the environmental protection expenditures as key independent variables. Models 15-16 include the variable on current expenditures (*EEX*), while Models 17-18 the variable on investments (*EINV*). While *EEX* turns negative and marginally statistically significant ($p < 0.10$) for product and for process innovation, *EINV* has a positive and statistically significant effect on product innovation ($p < 0.01$). In line with the definition, current expenditures are an operating cost deriving from those activities of the firms that pollute or cause any other damage to the environment. Accordingly, regions that register high current expenditures on GDP are more likely to have firms less concerned with a radical change of paradigm and want just to internalize the cost of polluting. This could be caused by a lax regional environmental regulation, specific choices of local firms, or industrial specialization in sectors that are highly polluting by nature. Contrary to current expenditures, investments require the introduction of new installations or equipment, or even intangible goods, which are all types of innovation new to the firm that could spur further innovation in the same firms and in the firms in the proximity. We only obtain this result for product innovation, which suggests that perhaps the

increased demand for new installation and equipment aimed at protecting the environment triggers innovation in components and final products rather than on process innovation.

With regard to the control variables, neither *business R&D per GDP* nor *public R&D per GDP* are statistically significant in any specifications. *Manufacturing specialization* is not statistically significant, as in previous specifications. Instead, the proxies for agglomeration economies are statistically significant for product innovation: *pop. density* is positive and its squared terms is negative, hence suggesting that until a certain threshold agglomeration favours innovation.

[TABLE 3 here]

Table 4 shows the second-step estimation for environmental management as key explanatory variable (Models 19-20). We obtain marginally statistically significant coefficients for product and process innovation (at $p < 0.10$). This suggests that environmental management tools in the region triggers a mechanism for which firms and organizations, once they start to monitor themselves about their environmental practices, stimulate new ideas and improvements that eventually translate in innovation. Again, here the increased probability to observe innovation at the firm-level in the region could be the result of the firms themselves introducing EMAS, or to knowledge spillover effects from interacting with firms and organizations that have introduced such tool in the region. However, it needs to be noted that this result is weak, perhaps because of the low number of new organizations adhering to the EMAS programme in each region.

With regards to the control variables, similarly to the estimations with the indicators of environmental technologies, we observe that *business R&D per GDP* is positive and significant for process innovation (although with a weaker level of significance) and *public R&D per GDP* is negative and significant for product innovation. The remaining controls *manufacturing specialization*, *pop. density* and *pop. density 2* are not significant.

[TABLE 4 here]

5 Conclusion

This paper aims at investigating whether different dimensions of being a "green" region could affect the firms' innovativeness. Through knowledge spillovers and proximity, firms present in such types of regions could face additional incentives to introduce innovation, besides the traditional firm- and regional-inputs to innovation. Using data on Spanish manufacturing firms and regions, we found that environmental technologies (especially in green energy), environmental expenditures

(especially in the form of investments), and – to a lesser extent - environmental management at the level of regions positively affect the probability of local firms of introducing innovation.

Our study contributes to the debate on whether regional determinants are important for firm innovation (Love and Roper, 2001). In particular, we find that specific environmental characteristics could affect micro innovation.

In addition, we contribute to the literature on the linkage between regional environmental determinants and firms' innovation, as the regional contributions to environmental innovation and overall innovation has received little attention, despite the regional level is considered important (Truffer and Coenen, 2012).

Table 1 – Number and percentage of firms introducing innovation in selected years

Year	Product Innovation		Process innovation		Total
	#	%	#	%	
2004	300	21.83	380	27.66	1374
2008	362	18.02	685	34.1	2009
2013	271	16.1	525	31.19	1683

Table 2 -FE panel, regional level: environmental technologies, 2004-2013

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC
Green Patents	-0.008	0.000												
	(0.011)	(0.009)												
Energy Patents			-0.010	0.007*										
			(0.012)	(0.004)										
Transportation Patents					0.042	-0.014								
					(0.026)	(0.027)								
Other Green Patents							-0.010	-0.016						
							(0.008)	(0.017)						
RTA Energy patents									-0.235	0.361***				
									(0.334)	(0.089)				
RTA Transport. patents											0.200*	-0.077		
											(0.110)	(0.105)		
RTA Other Green patents													-0.113	0.013
													(0.084)	(0.139)
Business R&D per GDP	-0.292	1.683**	-0.293	1.689**	-0.288	1.684**	-0.274	1.699**	-0.379	1.827**	-0.322	1.697**	-0.267	1.681**
	(0.871)	(0.680)	(0.866)	(0.720)	(0.958)	(0.690)	(0.909)	(0.678)	(0.896)	(0.697)	(0.956)	(0.678)	(0.890)	(0.687)
Public R&D per GDP	-2.007	1.817	-1.873*	1.665	-2.144*	1.844	-2.249*	1.558	-1.761*	1.339	-2.233**	1.881	-2.185*	1.832
	(1.183)	(1.231)	(1.041)	(1.201)	(1.051)	(1.235)	(1.227)	(1.404)	(1.003)	(1.189)	(1.035)	(1.246)	(1.189)	(1.224)
Manufacturing specialization	-0.019	0.077	-0.025	0.088	-0.018	0.079	-0.008	0.080	-0.017	0.087	-0.018	0.080	-0.006	0.076
	(0.093)	(0.051)	(0.091)	(0.053)	(0.084)	(0.051)	(0.091)	(0.053)	(0.089)	(0.053)	(0.086)	(0.051)	(0.092)	(0.052)
Pop. density	0.007	0.006	0.005	0.004	0.004	0.006	0.007	0.012	0.002	0.007	0.002	0.006	0.006	0.005
	(0.014)	(0.015)	(0.014)	(0.016)	(0.016)	(0.016)	(0.013)	(0.017)	(0.014)	(0.016)	(0.015)	(0.015)	(0.013)	(0.015)
Pop. density2	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.472	-3.587*	0.726	-3.638*	0.674	-3.596*	0.273	-4.187*	0.786	-3.774*	1.076	-3.750*	0.251	-3.546*
	(3.113)	(1.810)	(3.267)	(1.925)	(3.457)	(1.938)	(3.226)	(2.209)	(3.353)	(1.972)	(3.356)	(1.818)	(3.246)	(2.005)
Obs.	153	153	153	153	153	153	153	153	153	153	153	153	153	153
F	0.00	0.06	0.00	0.02	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.03
Log-plh	-139.28	-113.14	-139.06	-112.29	-137.29	-112.67	-139.62	-111.70	-139.11	-109.86	-137.35	-112.58	-139.45	-113.13

* p<0.10, ** p<0.05, *** p<0.01.
Robust errors in parentheses.

Table 3 -FE panel, regional level: environmental protection expenditures, 2008-2013

	Model 15	Model 16	Model 17	Model 18
	PROD	PROC	PROD	PROC
EEX	-0.901*	-0.845*		
	(0.086)	(0.076)		
EINV			0.734**	0.400
			(0.027)	(0.193)
Business R&D per GDP	0.516	0.827	-0.323	0.138
	(0.771)	(0.622)	(0.861)	(0.934)
Public R&D per GDP	1.368	0.563	1.879	0.003
	(0.550)	(0.794)	(0.426)	(0.999)
Manufacturing specialization	0.043	0.186	0.078	0.176
	(0.742)	(0.134)	(0.548)	(0.141)
Pop. density	0.272**	-0.112	0.287**	-0.097
	(0.015)	(0.277)	(0.013)	(0.337)
Pop. density2	-0.000**	0.000	-0.000**	0.000
	(0.019)	(0.482)	(0.016)	(0.624)
Constant	-34.126**	10.933	-34.168**	12.202
	(0.022)	(0.425)	(0.025)	(0.367)
Obs.	68	68	68	68
F	0.00	0.01	0.01	0.00
Log-plh	-37.51	-33.59	-38.99	-32.48

* p<0.10, ** p<0.05, *** p<0.01.
Robust errors in parentheses.

Table 4 -FE panel, regional level: environmental management, 2004-2013

	Model 19	Model 20
	PROD	PROC
EMAS	0.018*	0.020*
	(0.010)	(0.011)
Business R&D per GDP	-0.435	1.512*
	(1.009)	(0.732)
Public R&D per GDP	-2.095*	1.796
	(1.162)	(1.258)
Manufacturing specialization	-0.017	0.068
	(0.095)	(0.052)
Pop. density	0.003	0.006
	(0.015)	(0.014)
Pop. density2	-0.000	-0.000
	(0.000)	(0.000)
Constant	0.824	-3.418*
	(3.504)	(1.800)
Obs.	153	153
F	0.00	0.01
Log-plh	-139.60	-112.26

* p<0.10, ** p<0.05, *** p<0.01.
Robust errors in parentheses.

Appendix A.1 – Correlation, firm-level analysis

		1	2	3	4	5	6	7	8	9	10	11	Mean	SD
1	Size	1											4.194	1.453
2	Size 2	0.981***	1										19.705	13.482
3	in-house R&D intensity	0.152***	0.148***	1									0.005	0.017
4	Permanent R&D	0.397***	0.409***	0.282***	1								0.147	0.354
5	Foreign	0.445***	0.454***	0.039***	0.215***	1							0.150	0.357
6	Export	0.470***	0.433***	0.160***	0.252***	0.264***	1						0.654	0.476
7	Public R&D funding	0.340***	0.346***	0.363***	0.327***	0.094***	0.227***	1					0.126	0.332
8	Expansive market	0.114***	0.101***	0.059***	0.048***	0.038***	0.080***	0.076***	1				0.184	0.388
9	Stable market	0.009	0.009	-0.041***	-0.020***	0.007	-0.036***	-0.045***	-0.449***	1			0.472	0.499
10	Cooperation	0.225***	0.245***	0.144***	0.198***	0.099***	0.106***	0.220***	0.047***	-0.016**	1		0.030	0.171
11	High-tech sectors	0.215***	0.211***	0.255***	0.221***	0.236***	0.223***	0.217***	0.042***	-0.005	0.094***	1	0.239	0.427

* p<0.10, ** p<0.05, *** p<0.01.

Appendix A.2 – RE logit, firm-level determinants of innovation, 2004-2013

	Product	Process
Size	1.157***	1.079***
	(0.224)	(0.161)
Size 2	-0.057**	-0.059***
	(0.023)	(0.017)
in-house R&D intensity	16.629***	4.339**
	(2.174)	(1.725)
Permanent R&D	0.507***	0.506***
	(0.114)	(0.096)
Foreign	-0.271*	-0.133
	(0.138)	(0.110)
Export	0.860***	0.310***
	(0.126)	(0.087)
Public R&D funding	0.711***	0.528***
	(0.101)	(0.088)
Expansive market	0.123	0.561***
	(0.099)	(0.077)
Stable market	0.001	0.272***
	(0.082)	(0.062)
Cooperation	0.085	0.766***
	(0.172)	(0.157)
High-tech sectors	0.705***	0.148
	(0.132)	(0.098)
_cons	-7.277***	-5.604***
	(0.532)	(0.366)
lnsig2u		
_cons?????	1.709***	1.125***
	(0.069)	(0.060)
Obs.	16588	16739
Chi 2	0.00	0.00
Log-plh	-5452.88	-8032.54

* p<0.10, ** p<0.05, *** p<0.01.
Explanatory variables are 1-year lagged (except High-tech sectors).

Appendix B.1 – Correlation, regional analysis

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean	SD
1	Business R&D per GDP	1															0.528	0.396
2	Public R&D per GDP	0.314***	1														0.492	0.156
3	Manufacturing specialization	0.552***	-0.200***	1													16.852	6.164
4	Pop. density	0.376***	0.421***	-0.278***	1												159.605	175.261
5	Pop. density2	0.365***	0.459***	-0.255***	0.947***	1											56009.220	137770.300
6	Green Patents	-0.007	0.172**	-0.141*	-0.073	-0.081	1										18.687	9.689
7	Energy Patents	0.110	0.235***	-0.010	-0.113	-0.068	0.818***	1									13.463	9.227
8	Transportation Patents	0.053	-0.085	0.069	0.024	-0.005	0.065	-0.166**	1								1.347	2.779
9	Other Green Patents	-0.259***	-0.064	-0.340***	0.065	-0.026	0.431***	-0.063	-0.101	1							4.539	5.483
10	RTA Energy patents	0.146*	0.229***	-0.031	0.007	0.030	0.623***	0.814***	-0.209***	-0.094	1						-0.036	0.387
11	RTA Transport. patents	0.313***	0.144*	0.096	0.266***	0.210***	-0.013	-0.147*	0.759***	-0.142*	-0.057	1					-0.470	0.654
12	RTA Other Green patents	-0.073	0.116	-0.263***	0.199***	0.095	0.288***	-0.101	-0.131*	0.823***	0.010	-0.007	1				-0.204	0.589
13	EEX	0.175	0.169	0.435***	-0.374***	-0.366***	-0.089	0.012	-0.068	-0.228*	-0.045	-0.105	-0.092	1			0.767	0.508
14	EINV	0.457***	-0.009	0.781***	-0.396***	-0.396***	-0.076	0.070	-0.061	-0.314***	-0.009	0.003	-0.137	0.633***	1		1.593	0.767
15	EMAS	0.266	0.252	-0.038	0.448	0.392	-0.132	-0.139	-0.017	-0.016	-0.045	0.194	0.128	0.067	-0.058	1	2.603	4.528

* p<0.10, ** p<0.05, *** p<0.01.

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