

Determinants of green innovations: Firm-level evidence

*Iulia Siedschlag^{*a,b}, Stefano Meneto^{a,b} and Manuel Tong Koecklin^{a,b}*

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JEL Codes: D22, F23, L51, Q55

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1 Introduction

A large body of economic theory and recent international evidence have established that green innovation is a key driver of sustainable long-term economic growth (for a recent review see for example, Smulders, Toma, and Withagen 2014). Given well-known negative externalities associated with environmental challenges and specific market failures, it is also increasingly accepted that government actions are needed to foster green innovations (OECD 2011, UNEP 2011). Understanding what drives the propensity of firms to introduce innovations with environmental benefits could improve the knowledge-base of policies aiming to incentivise firms to invest in green innovations.

This paper examines factors that influence the propensity of firms to introduce green innovations. Using micro data from Ireland, we examine a range of factors suggested by previous international evidence including: environmental regulations, innovation inputs, firm-specific characteristics, spillovers from other firms with green innovations (in the same industry and in the same region), co-operation for innovation activities, and public funding. We consider all innovations with environmental benefits as well as two specific innovation categories, namely innovations with within firm environmental benefits and innovations with environmental benefits for the final consumer. Further, within these two broad innovation categories, we analyse green innovations by the type of environmental impact. In addition to average effects across all firms, to account for potentially different firm behavior, we analyse separately manufacturing and services firms and indigenous and foreign-owned firms.

The key results of this research indicate that environmental regulations, in-house research and development (R&D) activity and acquisition of capital assets are major drivers of green innovations. Larger firms are more likely to introduce green innovations. This result holds for all firms as well as all sub-samples of firms analysed with the exception of firms in services. The propensity of services firms to introduce green innovations increases with the share of green innovators in the same industry. Such a spillover effect is not identified in the case of the other groups of firms. Relative to foreign-owned firms, indigenous firms are more likely to introduce green innovations with benefits for the end user. This result holds across all firms as well as for manufacturing and services firms.

The remainder of this paper is organised as follows. Section 2 discusses the international evidence on determinants of green innovations based on firm-level analysis. Section 3 presents the empirical methodology. Data and descriptive statistics are discussed in Section 4. Section 5 discusses the empirical results. Finally, section 6 concludes.

2 Determinants of Green Innovations – International Evidence Based on Firm-Level Analysis

Green innovations include new or modified products, processes, practices, and systems, that aim at reducing or removing altogether the environmental damaging effect of economic activity (Horbach, Oltra, and Belin 2013; Rennings 2000). Although much of the recent literature is focused on factors underlying inventions with environmental benefits measured with patents, the empirical literature on the factors underlying the introduction of green innovations in a broader sense is still relatively small.

Existing international evidence based on firm-level analysis has identified several factors that influence the propensity of firms to introduce green innovations including: environmental regulations, innovation inputs, firm specific characteristics, competition, spill-overs from other green innovators, and public funding. This section summarizes evidence from firm level-analysis using data from the Community Innovation Surveys (Eurostat 2019).

2.1 Environmental Regulations

The hypothesis that environmental policy drives green innovations has been put forward by Porter (1991) and developed theoretically by Acemoglu et al. (2012). Following on from this literature, a large number of firm-level empirical studies have found that environmental regulations, including government legislation such as laws, acts, and directives, are an important driver for the introduction of green innovations. However, a number of studies have found that environmental regulations had no effect or negative effects on the propensity of firms to introduce green innovations.

In the case of Germany, Horbach (2008) investigates the determinants of green innovations where the importance of compliance with environmental regulatory measures is used as an indicator for environmental policy over the period 1993-2004. The author finds a statistically significant and positive effect of environmental regulations, both present and expected, on the introduction of green innovations. Also in the case of Germany, Rennings and Rammer (2011) investigate drivers of green innovation at a disaggregated sectoral level and conclude that the effect of environmental regulations on innovation success varies by field of environmental policy. Among their results, and partially in contrast to Horbach (2008), they find a negative impact of regulations on innovation success in the water management and power generation sectors. On the other hand, Horbach, Rammer, and Rennings (2012) find positive and statistical significant effects of present and expected regulation on reducing firms' emissions of noise, water, and air. These findings are similar to those of Ketata, Sofka, and Grimpe (2015).

In the case of Italy, Cainelli, Mazzanti, and Borghesi (2012) find that the European Union Emissions Trading System (EU ETS), has a marginal positive effect on the introduction of green innovations. This effect applies only in the case of innovations in the areas of energy efficiency and of reductions of atmospheric and water emissions. However, using the same empirical methodology, Borghesi, Cainelli, and Mazzanti (2015) find that the EU ETS is negatively associated with green innovations. The authors argue that this result might be related to pre-emptive behaviour from early moving firms. In contrast to Borghesi, Cainelli, and Mazzanti (2015), Peñasco, del Río, and Romero-Jordán (2017) conclude that the EU ETS play a significant and positive role on the introduction of green innovations in Spain.

Cainelli, D'Amato, and Mazzanti (2015) find that the policy commitment of a region to improve separated waste collection increases the likelihood of a firm to introduce waste-related innovations. The study by Leoncini, Montresor, and Rentocchini (2016) focuses on drivers of innovations dealing with reductions of CO₂ from 2006 and 2010. The authors find a highly significant and positive effect of environmental regulations on the reduction of a firm's footprint.

In the case of the UK, Ramanathan et al. (2013) find that environmental regulations have a negative effect on green innovation in the short run, similarly with the results of Borghesi Cainelli, and Mazzanti (2015).

Horbach and Rammer (2018) examine the role played in the process of diffusion of green technologies and find that expected environmental regulations played a more influential role for renewable energy innovations, as opposed to current regulations.

Empirical studies on the effects of environmental regulation on the propensity of firms to introduce green innovations in small open economies find similar results to those for large economies such as Germany and Italy.

Using data from Ireland, Doran and Ryan (2012) examine the factors driving green innovations, with a particular attention to the role of government regulations to incentivise the introduction of these

innovations. Their results indicate that the propensity of firms to introduce green innovations is influenced by current and expected environmental regulations. Veugelers (2012) found similar results in the case of Belgium. In addition, her analysis uncovers that developers of green innovations are more responsive to policy intervention than adopters of green innovations.

Van Leeuwen and Mohnen (2017) add to the literature by identifying both direct and indirect effects of environmental regulations on the introduction of green innovations in the Netherlands. In addition, the authors find complementary effects of introducing pollution-reducing and resource-saving green innovations.

Using data from South Korea, Castellacci and Lie (2017) find that environmental policy plays an important role on firms' green innovations in the waste and pollution-reducing sectors.

Cross-country studies based on firm-level data provide useful evidence highlighting similarities as well as unique features on the environmental regulations' effect on the introduction of green innovations. Horbach, Oltra, and Belin (2013) find that environmental regulations play a major role in the introduction of green innovations in France and Germany. However, it emerges that universities in France, compared to universities in Germany, have a greater role as cooperation partners for green innovations.

Using data from 22 EU countries,² Crespi, Ghisetti, and Quatraro (2015) uncover the relevant effect of announced future environmental regulations as a driver of green innovations in the area of improving recycling after sales use, carbon dioxide emissions, material use, and different pollution after sales use.

A study by Horbach (2016) on the determinants of green innovations in 19 EU countries³, finds that environmental regulations play a more important role for the introduction of green innovations with environmental impacts on air, soil, and water than in sectors that deal with energy and material savings. This result is more pronounced for Eastern European countries than in Western Europe.

The study by Garrone, Grilli, and Mrkajic (2018) focuses on the role of regulatory pressure on firms' propensity to adopt energy efficiency innovations in 9 EU countries.⁴ The authors show that environmental regulations promote the creation of product and process innovation with green features. Stucki et al. (2018) analyse firms in Austria, Germany, and Switzerland and find that, on average, regulations have a negative effect on the introduction of green innovations. In particular, the authors find that process innovations are less impacted by regulation than product innovations. The evidence indicates a positive effect of environmental regulations on technological leaders only, as opposed to a negative effect on laggard firms.

2.2 Innovation Inputs

Another important factor for the introduction of green innovations are innovation inputs, such as investment in research and development (R&D), co-operation with public and private entities, and acquisition of capital assets and of external knowledge.

Horbach (2008) finds that improvements to German firms' technological capabilities increase the likelihood of introducing green innovations. Moreover, from the study of Horbach (2014) it emerges

² Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherland, Poland, Portugal, Romania, Slovakia and Sweden, 22 in total.

³ Bulgaria, Cyprus, Czech Republic, Germany, Estonia, Finland, France, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Portugal, Romania, Sweden, and Slovakia

⁴ Bulgaria, Czech Republic, Germany, Hungary, Italy, Lithuania, Portugal, Romania, and Slovakia.

that external knowledge sources, such as regional proximity to research centres and universities, increases the likelihood of adopting green innovations, compared to other innovations.

Using data from Italy, Cainelli, Mazzanti, and Montresor (2012) find that foreign ownership impacts on the likelihood of introducing green innovations conditional on a firm's cooperation with its own suppliers. Borghesi, Cainelli, and Mazzanti (2015) uncover the importance of acquisition of external knowledge as the most relevant driver of green innovation in Italy. Using a panel dataset of Italian firms from 2005 to 2010, Cainelli, De Marchi, and Grandinetti (2015) conclude that R&D activity, cooperation with suppliers and universities, acquisition of external knowledge and equipment are more relevant for green innovations than the case of other innovations.

Peñasco, del Río, and Romero-Jordán (2017) show that in Spain firms that cooperate with national and international partners increase their likelihood of introducing green innovations and that the effect of cooperation with international partners is larger than the effect of cooperation with national partners. The study by Badillo and Moreno (2018) using data on Spanish firms between 2004 and 2011 reinforce the findings of Peñasco et al. (2017). Kunapatarawong and Martínez-Ros (2019) conclude that as firms increase in size, there is a shift from internal to external knowledge when developing green innovations.

Doran and Ryan (2012) find that strengthening the cooperation between Ireland's firms in the supply chain increases the likelihood of developing green innovations.

Castellacci and Lie (2017) show that green innovations by firms in South Korea in the carbon dioxide and waste reducing sectors are driven mainly by internal R&D capability and strong links to public research institutes and universities.

In a cross-country study,⁵ Jaumotte and Pain (2005) find evidence indicating that past R&D and patenting activity as well as greater co-operation between firms and with government research organisations and universities are important determinants of green innovations. Horbach (2016)⁶ concludes that internal R&D plays a crucial role for innovations with environmental benefits in the area of material and energy savings.

2.3 Firm-Specific Factors

International evidence indicates that firm-specific factors play a significant role in the decision of firms to introduce green innovations. Horbach (2008) finds that German firms in the electrical machinery and motor vehicles industry, characterised by high export shares and thus exposed to international competition, are more likely to introduce green innovations than other firms. Horbach, Rammer, and Rennings (2012) show that cost saving factors also drive green innovations. These factors are in turn influenced by energy and raw material prices, and taxation. Horbach (2014) finds that energy intensive sectors, such as mining and chemicals, are more likely to adopt green innovations. Additionally, the author shows that green innovations "seem to be a chance for under-developed regions looking for new business activities because they are more likely in regions characterized by high poverty rates". Ketata, Sofka, and Grimpe (2015) show that in the case of firms in Germany, investment in employee training has a greater impact than R&D expenditures for the adoption of green innovations.

⁵ Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and the UK.

⁶ Bulgaria, Cyprus, Czech Republic, Germany, Estonia, Finland, France, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Portugal, Romania, Sweden, and Slovakia (19 countries)

Furthermore, Cantner et al. (2016) find that the firm's network size⁷ for the photovoltaic sector is influenced by the engagement in the international market and the size of export markets.

A study by De Marchi (2010) on firms in Spain finds a negative but statistically not significant effect of exports on the probability to introduce green innovations suggesting that local markets may be more important for green innovations than for other types of innovations. Peñasco, del Río, and Romero-Jordán (2017) corroborate the results of De Marchi (2010) by also providing evidence that the outcome does not change whether the export market is European or extra European. Costa-Campi, García-Quevedo and Martínez-Ros (2017) show that firms in Spain that are more competitive and that have a greater international market are more likely to introduce green innovations. Using a panel dataset from 2004 to 2011, Badillo and Moreno (2018) find that a firm's absorptive capacity is an important determinant of the likelihood of green innovations.

In a study of the Emilia Romagna region in Italy by Cainelli, Mazzanti, and Montresor (2012), no evidence is found with respect to foreign ownership of a firm as determinant of green innovation. Borghesi, Cainelli, and Mazzanti (2015) show that a significant determinant of green innovation is the intensity of energy expenditures of a given firm, arguing that the cost saving motive might be the underlying driver of green innovation. Leoncini, Montresor, and Rentocchini (2016) show that the international orientation⁸ of a firm acts as a determinant for the adoption of green innovations. Antonioli and Mazzanti (2016) conclude that cooperative industrial relations, measured as union involvement of a particular firm in Italy, increase the likelihood of introducing green innovations. Antonioli, Borghesi and Mazzanti (2016) show that both training activities and the geographical position of a given firm in Italy both increase the likelihood of introducing green innovations.

In a study of firms in Croatia, Aralica, Račić, and Radić (2008) find that the likelihood to introduce green innovations increases with firm size.

Jaumotte and Pain (2005) investigate the determinants of green innovation in a number of European countries⁹ and find that qualified personnel had a positive and significant effect on the introduction of green innovation. In a study of firms from 19 European countries¹⁰, Horbach (2016) shows that exporting does not play a crucial role for the introduction of green innovations. Stucki et al. (2018) find that for firms in Austria, Germany, or Switzerland, export intensity has no impact on the likelihood of introducing green innovations.

2.4 Competition

Horbach (2008) finds that German firms in the electrical machinery and motor vehicles industry, characterised by high export shares and thus exposed to international competition, are more likely to introduce green innovations than other firms. Horbach (2014) and Horbach, Rammer, and Rennings (2012) find evidence showing that the prospect of entrance of new firms acts as a determinant of green innovations for German firms. From a study by Horbach and Rammer (2018), a positive correlation is found between higher international competition and the likelihood of introducing renewable energy innovations. On the other hand, Ziegler (2008) finds no statistically significant effect of competition on the introduction of green innovations in Germany.

⁷ Given by the number of nodes, which represent individual inventors and could be interpreted as the attractiveness of the research field.

⁸ Measured as the ratio of export sales to total sales.

⁹ Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and the UK.

¹⁰ Bulgaria, Cyprus, Czech Republic, Germany, Estonia, Finland, France, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Portugal, Romania, Sweden, and Slovakia.

2.5 Spillovers

Spillovers from other innovators/foreign affiliates play an important role in the introduction of green innovations. In the case of Italy, Antonioli, Borghesi and Mazzanti (2016) find that being based in a certain municipality with a higher share of green innovations increases the likelihood that a firm will introduce green innovations, as firms learn about the benefits of green innovations. Horbach and Rammer (2018) show that both the orientation of a region towards 'green issues'¹¹ and the physical proximity to sources of renewable energy are positively linked to the introduction of green innovations.

2.6 Public Funding

Cainelli, Mazzanti, and Borghesi (2012) find that local public funding and group membership seem to be the most relevant determinants for the introduction of radical green innovations for firms based in Italy. Further, Cainelli, and Mazzanti (2013) find that public funding played an important role for the introduction of innovations with environmental benefits in the areas of carbon abatement and energy efficiency in the Italian service industries. However, Borghesi, Cainelli, and Mazzanti (2015) find no effect of public funding on the innovation performance of firms in the sectors under the EU ETS regulations. In a study on South Korea, Castellacci and Lie (2017) find that public funding is an important determinant of innovations with environmental benefits in the area of waste and carbon dioxide reducing sectors.

Peñasco, del Río, and Romero-Jordán (2017) show that in Spain, international public subsidies do not increase the likelihood of introducing green innovations, whereas national public funding does. In contrast to these results, Rogge and Schleich (2018) find that public funding to German firms matters for the introduction of green innovations conditional on firms' accessibility to both domestic and EU funding. Using data from 16 EU countries,¹² Jaumotte and Pain (2005) find that green innovations in small firms are dependent on the availability of finance and co-operation to a larger extent than in larger firms.

In summary, international evidence uncovers a range of factors which influence the decisions of firms to introduce green innovations: environmental regulations; innovation inputs such as investment in R&D and access to external knowledge; firm-specific factors such as energy intensity, human capital, absorptive capacity; international and domestic competition; spillovers from other green innovators; and public funding. Taking this international evidence as point of departure, we examine the importance of these factors for the propensity of firms in Ireland to introduce green innovations.

3 Empirical Methodology

To identify the main determinants of firms' decisions to introduce innovations with environmental benefits we estimate econometric models specified as follows:

$$\text{Prob}(Y_i=1|X_i) = F(X_i, \beta) \tag{1}$$

The dependent variable Y_i is a binary variable that takes the value 1 if firm i implemented any innovation with environmental benefits during the analysed period. Further, we disaggregate the dependent variable to account for types of environmental innovation according to the final beneficiary (the firm itself or the final consumer) and different environmental impact areas (reduced material or

¹¹ Measured by the share of green voters within a region.

¹² Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and the UK.

water use; reduced energy use or CO2 footprint; reduced air, water, noise or soil pollution; renewable energy sources; recycled waste, water or materials; facilitated recycling after use; more durable products).

The vector X_i includes the explanatory variables: an indicator variable for environmental regulations (a set of two dummies, which take the value 1 if the firm implemented procedures to regularly identify and reduce environmental impacts before and after the analysed period, respectively); innovation inputs (in-house R&D, external R&D, acquisition of capital assets, acquisition of external knowledge, and other innovation inputs); firm-specific factors including their productivity (at the beginning of the analysed period), size (employment quartiles), export performance (whether they exported to Europe or other markets), and ownership (indigenous or foreign-owned); a measure of spillovers from other green innovators (the NACE 2 industry-level share of firms that implemented an environmental innovation, other than a given firm i ¹³). The firm-specific factors in the baseline model are obtained from the Community Innovation Survey 2014 that includes information on green innovations introduced by firms over the period 2012-2014, but in further estimations we add control variables from the Census of Industrial Production (CIP) and the Annual Services Inquiry (ASI). These additional variables are lagged by one year with respect to the analysed period. Further co-variables control for the role of public funding in introducing green innovations (three binary variables taking the value 1 if the firm obtained public financial support to implement green innovations from local/regional authorities, the central government or the European Union) and innovation co-operation (eight categorical variables accounting for co-operations for green innovations with: enterprises within the same enterprise group; suppliers; private and public clients; competitors; consultants; universities and the government). Finally, we control for unobserved sector characteristics that could influence the propensity of firms to introduce green innovations.

Initially, we estimate this model for the entire sample of firms. Subsequently, we replicate the analysis for four groups of firms: manufacturing, services, indigenous and foreign-owned firms. As mentioned above, in further estimations, we augment the baseline model specification by incorporating firm-specific factors using data from the CIP and ASI. These additional co-variables also include unobserved regional characteristics and the lagged dependent variables to control for persistence in the introduction of green innovations. We obtain the latter from the Community Innovation Survey 2008 for Ireland with information on green innovations introduced over the period 2006-2008. More detailed definitions of variables used in the empirical analysis and their data sources are given in Table A1 in the Appendix.

4 Data and Descriptive Analysis

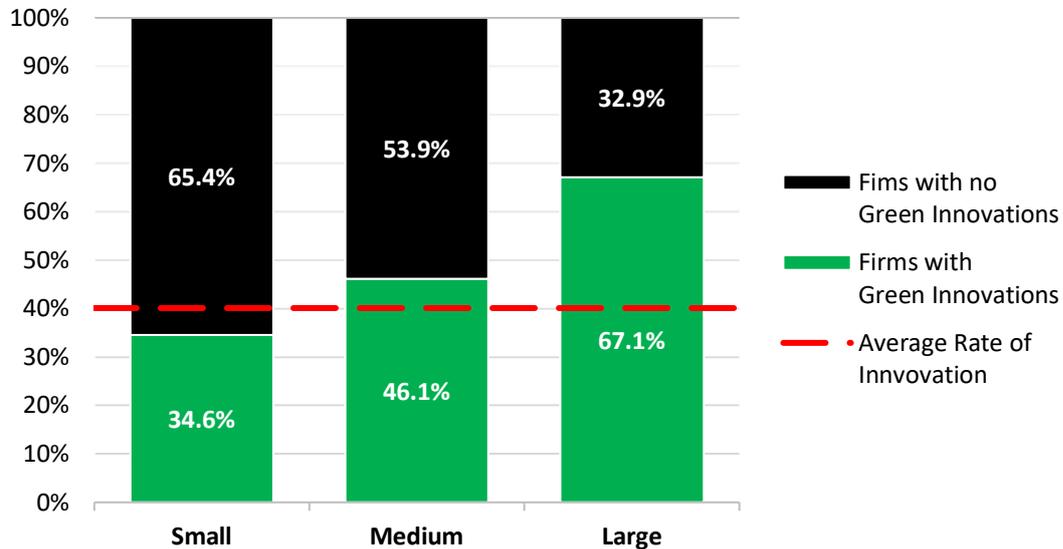
The main data source for this research is the Community Innovation Survey (CIS) 2014 for Ireland undertaken by the Central Statistics Office (CSO). The data set contains information on innovation activities of 3,036 firms over the period 2012-2014. For the empirical approach, we also count on firm-specific data from the Census of Industrial Production (CIP) and the Annual Services Enquiry (ASI), also provided by the CSO, for 2011. Additionally, we use data on innovation activity over the period 2006-2008 from the CIS 2008 to account for persistence in the introduction of green innovations. This analysis is limited to these two surveys because questions about innovations with environmental benefits have not been included in other Community Innovation Surveys conducted in Ireland.

Figure 1 plots the proportion of firms with any innovation with environmental benefits by firm size. The CIS considers three size categories: small, medium and large firms. It is clear from Figure 1 that

¹³ Model specifications include measures of spillovers accounting for innovations with environmental benefits within the enterprise and for the final user, separately.

green innovations are more likely the larger firms are. While only 34.6% of small firms introduced green innovations between 2012 and 2014, 67.1% of large firms did so. As a result, an average of 40.1% of firms surveyed introduced innovations with environmental benefits over that period.

Fig. 1: Green Innovation Rate by Firm Size

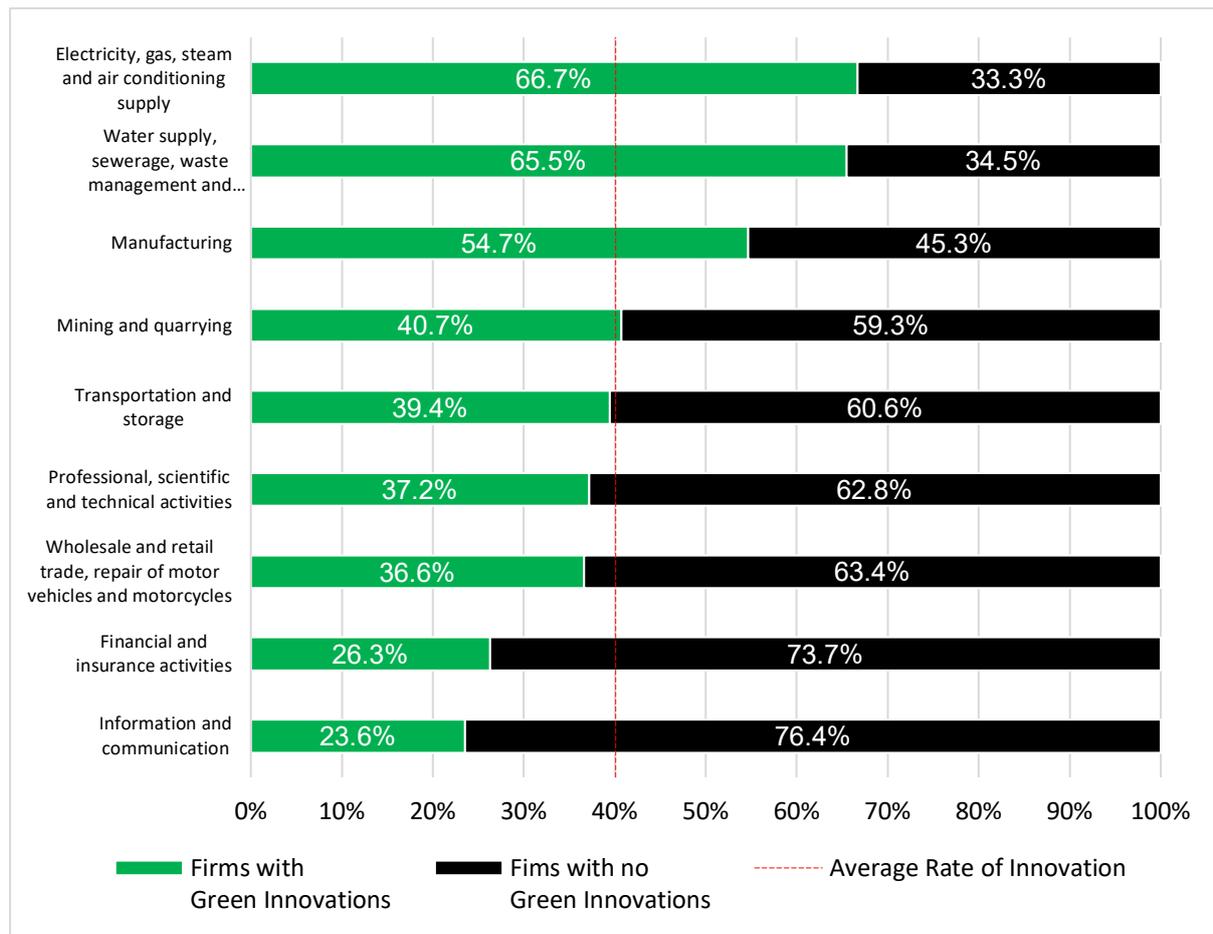


Source: Authors' calculations based on data from the CSO.

Figure 2 replicates the above analysis across sectors, according to the NACE Rev.2 industry classification. Sector-specific rates for green innovations vary as shown below. Utility industries such as electricity, gas, water and sewerage have the highest green innovation rate (over 65%) followed by manufacturing (55%), mining and quarrying (41%) and services. Across the services sector, the highest green innovation rate is in Transport and storage and the lowest in information and communication.

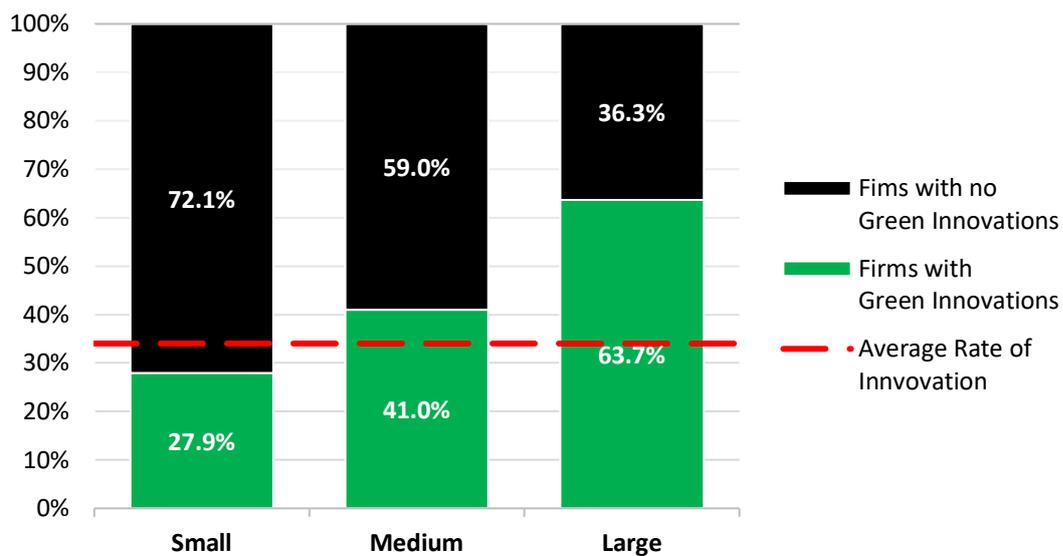
The Community Innovation Survey distinguishes two categories of green innovations according to the final beneficiary: innovations with environmental benefits within the enterprise itself and innovations with environmental benefits for the final consumer. Figure 3 presents summary statistics for green innovations with benefits within the enterprise by firm size. Overall, 34% of firms reported the introduction of this type of green innovations between 2012 and 2014. The innovation rate increases with firm size. Large and medium-sized firms have rates above the average innovation rate across all firms: 63.7% and 41.0%, respectively.

Fig. 2: Green Innovation Rate by Sector



Source: Authors' calculations based on data from the CSO.

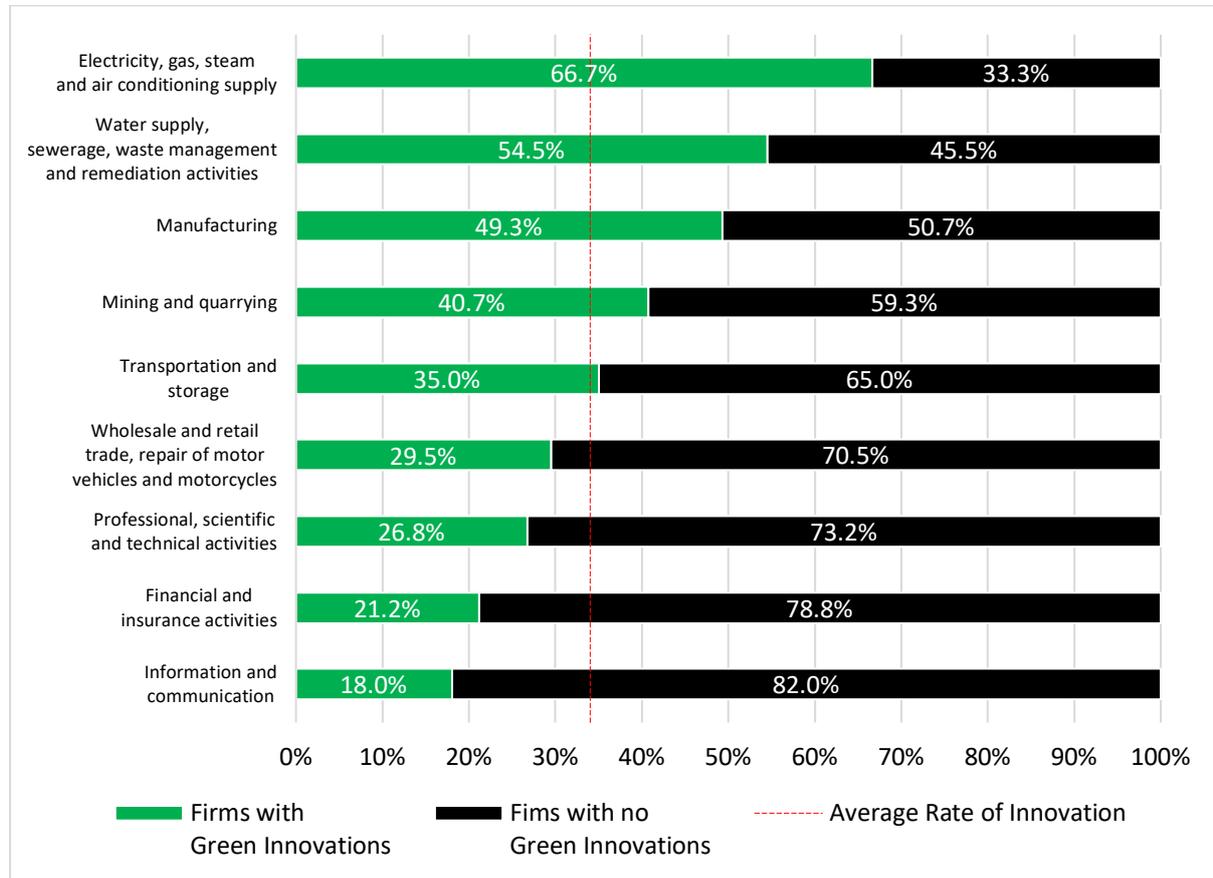
Fig. 3: Innovation Rate for Green Innovations with Benefits within the Enterprise By Firm Size



Source: Authors' calculations based on data from the CSO.

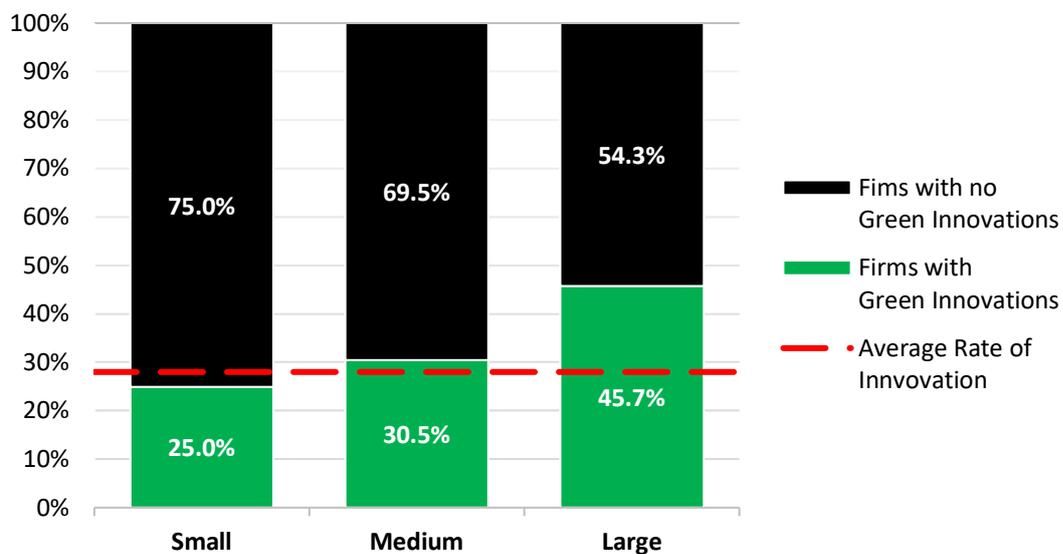
Figure 4 shows summary statistics of green innovations within the enterprise across sectors, with similar results to those for all green innovations. A difference worth noting is that the innovation rate for Transportation and Storage is higher than the average rate.

Fig. 4: Innovation Rate for Innovations with Benefits for the Enterprise by Sector



Source: Authors' calculations based on data from the CSO.

Fig. 5: Innovation Rate for Green Innovations with Benefits for the Final Consumer by Firm Size

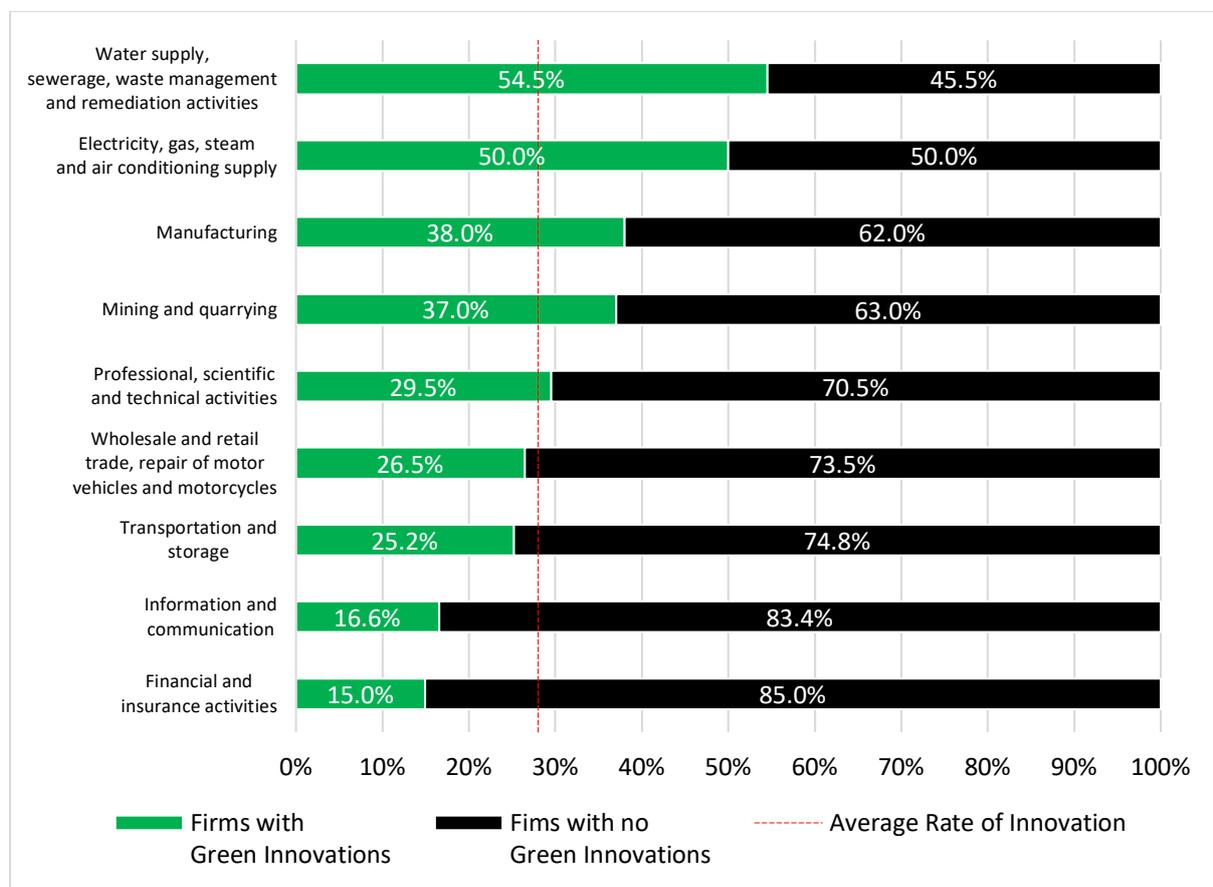


Source: Authors' calculations based on data from the CSO.

Figure 5 shows the distribution of innovations with environmental benefits for the final consumer across firm sizes. This type of green innovations tends to be less frequent than green innovations with benefits for the enterprise. Only 28% of responding firms report to have undertaken any green innovation that favours the final consumer. Once again, we find that the likelihood of introducing green innovations with benefits for the final user increases with firm size.

Figure 6 shows summary statistics of green innovations with benefits for the final consumer across sectors. While the sectoral patterns are broadly similar to those for all green innovations, a number of differences stand out. Firms in Professional, Scientific and Technical Activities report a larger rate of this type of green innovations than the average across all firms. Further, firms in Transportation and Storage with a higher than average rate of green innovations with benefits for the enterprise have an innovation rate below the average for green innovations with benefits for the final consumer.

Fig. 6: Innovations with Environmental Benefits for the Final Consumer by Sector



Source: Authors' calculations based on data from the CSO.

5 Econometric Results

5.1 All green innovations

Table 1 shows the estimates of the baseline model on determinants of any green innovations across all firms as well as subsamples of firms in manufacturing, services, indigenous and foreign-owned firms. The results for all firms shown in column 1 indicate that, on average, the propensity to introduce green innovations is higher for firms having in place procedures to regularly identify and reduce firm's environmental impacts. Having in place such procedures in the period before 2012, increases the probability to introduce green innovations by 9 percentage points. The effect is higher for environmental regulations implemented during the analysed period 2012-2014, 25.6 percentage points. Looking at different groups of firms, environmental regulations implemented before 2012, had the strongest effect on the propensity of services firms to introduce green innovations (13.8 percentage points) while they did not matter significantly for the introduction of green innovations by manufacturing firms. Previous environmental regulations had a stronger effect for foreign-owned firms (11.1 percentage points) relative to indigenous firms (8.9 percentage points). Environmental regulations implemented or changed significantly during the 2012-2014 period had positive and significant effects on the introduction of green innovations in all groups of firms with the strongest effect for manufacturing firms (29.1 percentage points).

In terms of innovation inputs, the propensity of firms to introduce green innovations is higher for firms with: in-house R&D; acquisition of machinery, equipment, software and buildings; acquisition of other external knowledge from other enterprises or institutions; innovation activities other than product and process innovation (non-technological innovations). This pattern is similar for indigenous firms while in the case of foreign owned firms only the acquisition of machinery, equipment, software and buildings is positively and significantly associated with the introduction of green innovations. In comparison to the average effects across all firms, for manufacturing firms in-house R&D and the acquisition of other external knowledge do not affect significantly the propensity to introduce green innovations. Firms in services have a similar behaviour as the average firm with the exception of other non-technological innovations which do not have a significant effect on the introduction of green innovations.

Larger firms are more likely to introduce green innovations. This result holds for all firms as well as all subsamples of firms with the exception of firms in services. Export participation does not appear to affect the propensity of firms to introduce green innovations. In contrast, the propensity of services firms to introduce green innovations is higher for firms in the same industry with green innovators. This spillover effect is not identified in the case of the other groups of firms. Further we find only limited evidence on public funding as a driver for the introduction of green innovations. More specifically, our results indicate a positive albeit marginally significant effect in the case of funding from local authorities. This effect appears to be driven by firms in services while it does not appear in the case of the other groups firms. Finally, our results indicate that firms engaged in co-operation for innovation with firms in the same enterprise group, and with competitors are more likely to introduce green innovations. The effect of co-operations with firms in the same enterprise group is present for foreign-owned firms, while the positive effect of co-operation with competitors is identified for firms in services and for indigenous firms. For manufacturing firms, co-operation with private clients increase their propensity to introduce green innovations.

Table 1: Determinants of green innovations – all green innovations

Dep. Var.: Innovation with environmental benefits 2012-2014	All firms	Manufacturing	Services	Indigenous	Foreign-owned
Environmental regulations					
Pre-2012	0.092*** (0.020)	0.012 (0.033)	0.138*** (0.025)	0.089*** (0.023)	0.111*** (0.035)
Post-2012	0.256*** (0.018)	0.291*** (0.028)	0.242*** (0.025)	0.263*** (0.022)	0.236*** (0.034)
Innovation inputs					
In-house R&D	0.063*** (0.024)	0.019 (0.037)	0.069** (0.031)	0.074*** (0.028)	0.003 (0.048)
External R&D	0.000 (0.028)	0.044 (0.047)	-0.030 (0.036)	0.008 (0.034)	-0.014 (0.050)
Machinery, equipment, software & buildings	0.106*** (0.020)	0.134*** (0.034)	0.096*** (0.026)	0.108*** (0.023)	0.090** (0.043)
Other external knowledge	0.063** (0.026)	0.007 (0.045)	0.095*** (0.033)	0.082*** (0.030)	-0.0123 (0.056)
Other innovation activities	0.060** (0.029)	0.086* (0.047)	0.040 (0.038)	0.075** (0.034)	0.040 (0.055)
Firm-specific factors					
Productivity 2012	-0.002 (0.003)	-0.004 (0.006)	0.000 (0.003)	-0.002 (0.003)	0.001 (0.006)
Size (employment quartile)	0.026*** (0.008)	0.048*** (0.015)	0.011 (0.010)	0.031*** (0.009)	0.019 (0.018)
Exported to Europe	-0.015 (0.019)	-0.023 (0.037)	-0.010 (0.023)	-0.029 (0.022)	0.036 (0.047)
Exported to other destinations	-0.021 (0.021)	-0.045 (0.034)	-0.020 (0.026)	-0.022 (0.025)	-0.012 (0.041)
Ownership					
Indigenous firm	0.007 (0.022)	0.026 (0.040)	0.011 (0.026)		
USA ownership					-0.067* (0.039)
EU ownership					0.010 (0.044)
Spillovers (industry level)					
	-0.123 (0.110)	-0.032 (0.123)	0.610*** (0.145)	-0.151 (0.125)	0.046 (0.216)
Public funding					
Local/Regional authorities	0.084* (0.046)	0.035 (0.067)	0.145** (0.062)	0.072 (0.052)	0.172 (0.108)
Central government	0.012 (0.030)	0.053 (0.042)	-0.076* (0.043)	-0.003 (0.034)	0.084 (0.062)
European Union	0.011 (0.059)	0.074 (0.080)	-0.066 (0.098)	0.036 (0.062)	-0.121 (0.149)
Co-operation partners					
Enterprise group	0.075* (0.039)	0.079 (0.075)	0.071 (0.047)	0.020 (0.052)	0.112* (0.061)
Suppliers	0.020 (0.041)	0.096 (0.078)	0.027 (0.049)	0.008 (0.048)	0.039 (0.079)
Private clients	0.071 (0.045)	0.155* (0.082)	-0.012 (0.058)	0.090 (0.055)	0.057 (0.076)

Public clients	-0.017 (0.060)	-0.040 (0.095)	0.024 (0.077)	0.009 (0.072)	-0.041 (0.117)
Competitors	0.121** (0.059)	0.021 (0.086)	0.167** (0.076)	0.134** (0.066)	0.123 (0.144)
Consultants, private R&D	-0.010 (0.050)	-0.114 (0.091)	0.032 (0.061)	-0.041 (0.059)	0.0617 (0.083)
Universities, HEI	-0.024 (0.046)	0.066 (0.079)	-0.101 (0.066)	-0.054 (0.053)	0.027 (0.087)
Government	-0.045 (0.059)	-0.048 (0.097)	-0.019 (0.085)	-0.049 (0.069)	0.057 (0.151)
Sector fixed effects	Yes	No	No	Yes	Yes
N	2763	854	1827	2137	624
Pseudo R ²	0.220	0.267	0.167	0.212	0.274
Chi2	686.8	278.0	353.9	504.9	200.5

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

5.2 Green innovations with benefits for the enterprise and for the end user

Tables 2 and 3 show the results of determinants of green innovations with enterprise benefits and for the end user, respectively. A number of similarities and differences emerge. On the similarities side, environmental regulations play an important role in driving both types of green innovations with a similar pattern (no significant effect of previous regulations in the case of manufacturing firms). In terms of innovation inputs, in-house R&D activity is an important driver of both types of green innovations across all firms and for indigenous firms and no significant effect in the case of foreign-owned firms. While in-house R&D increases the likelihood of green innovations with benefits for services firms, it does not have a significant effect in the case of green innovations with benefits for the end user in services. In the case of manufacturing firms, in-house R&D is positively associated with the introduction of green innovations with benefits for the end user but not in the case of green innovations with enterprise benefits. Acquisitions of capital assets is an important driver of green innovations with enterprise benefits as well as of green innovations with benefits for the end user for all firms and for all groups of firms with the exception of green innovations with benefits for the end user in manufacturing. Acquisition of other external knowledge increases the propensity of indigenous firms to introduce both types of green innovations while it does not appear to matter in the case of the other groups of firms. Other non-technological innovation activities have a significant effect on the propensity of all firms to introduce green innovations with enterprise benefits as well as in the case of manufacturing and indigenous firms. In contrast, other non-technological innovation activities do not matter for the introduction of green innovations with benefits for the end user. Larger firms are more likely to introduce both types of green innovations, with a stronger effect in the case of green innovations with enterprise benefits introduced by manufacturing firms and by indigenous firms. Firm size has also a strong effect on the propensity of indigenous firms to introduce green innovations with benefits for the end user. While export participation does not affect the propensity of firms to introduce green innovations with enterprise benefits, indigenous and manufacturing exporters to European countries are less likely to introduce green innovations with benefits for the end user. Spillovers from green innovators in the same industry play an important role for the introduction of both types of green innovations in services. Public funding from local authorities appears to incentivise firm in services to introduce green innovations with enterprise innovations. There is no evidence of

similar effects in the case of government and EU funding. Relative to other firms, indigenous firms are more likely to introduce green innovations with benefits for the end user. The result is stronger in the case of manufacturing firms in comparison to services firms. In terms of co-operation for innovation activities, co-operation with firms from the same enterprise group and with competitors are important drivers of both types of green innovations with stronger effects in the case of innovations with environmental benefits for the end user. In this latter case, co-operation with competitors increase the likelihood of the introduction of green innovations for all groups of firms with the largest effects found for manufacturing firms and for foreign-owned firms.

Table 2: Determinants of green innovations – green innovations with within firm benefits

Dep. Var.: Innovation with environmental benefits within the enterprise 2012-2014	All firms	Manufacturing	Services	Indigenous	Foreign-owned
Environmental regulations					
Pre-2012	0.071*** (0.019)	0.011 (0.033)	0.101*** (0.023)	0.068*** (0.022)	0.086** (0.035)
Post-2012	0.247*** (0.017)	0.270*** (0.028)	0.237*** (0.022)	0.249*** (0.020)	0.247*** (0.032)
Innovation inputs					
Inhouse R&D	0.061*** (0.023)	0.004 (0.037)	0.082*** (0.029)	0.065** (0.027)	0.024 (0.046)
External R&D	-0.020 (0.026)	0.010 (0.045)	-0.043 (0.033)	-0.016 (0.031)	-0.021 (0.047)
Machinery, equipment, software & buildings	0.101*** (0.020)	0.127*** (0.034)	0.091*** (0.024)	0.108*** (0.022)	0.072* (0.041)
Other external knowledge	0.038 (0.025)	0.036 (0.044)	0.051 (0.031)	0.054* (0.029)	-0.024 (0.053)
Other innovation activities	0.053* (0.027)	0.082* (0.046)	0.035 (0.034)	0.063** (0.031)	0.045 (0.052)
Firm-specific factors					
Productivity 2012	-0.002 (0.002)	-0.001 (0.006)	-0.001 (0.003)	-0.003 (0.003)	0.002 (0.005)
Size (employment quartile)	0.027*** (0.008)	0.058*** (0.015)	0.012 (0.009)	0.030*** (0.008)	0.031* (0.018)
Exported to Europe	-0.010 (0.019)	0.016 (0.039)	-0.017 (0.021)	-0.023 (0.021)	0.044 (0.046)
Exported to other destinations	-0.025 (0.020)	-0.030 (0.034)	-0.032 (0.025)	-0.022 (0.024)	-0.033 (0.040)
Ownership					
Indigenous firm	-0.003 (0.021)	0.023 (0.040)	-0.005 (0.024)		
USA ownership					-0.053 (0.039)
EU ownership					0.038 (0.042)
Spillovers (innovations with benefits within the enterprise, industry level)	-0.043 (0.104)	-0.052 (0.128)	0.685*** (0.139)	-0.093 (0.122)	0.150 (0.196)
Public funding					
Local/Regional authorities	0.048	-0.006	0.105*	0.041	0.106

	(0.043)	(0.066)	(0.058)	(0.048)	(0.105)
Central government	0.009	0.038	-0.064	-0.015	0.100*
	(0.028)	(0.042)	(0.040)	(0.032)	(0.059)
European Union	-0.008	0.095	-0.132	0.007	-0.038
	(0.055)	(0.079)	(0.090)	(0.059)	(0.125)
Co-operation partners					
Enterprise group	0.060*	0.049	0.060	-0.021	0.121**
	(0.036)	(0.070)	(0.043)	(0.047)	(0.061)
Suppliers	-0.005	0.084	-0.017	-0.026	0.018
	(0.038)	(0.073)	(0.046)	(0.045)	(0.073)
Private clients	0.078*	0.098	0.031	0.111**	0.043
	(0.042)	(0.074)	(0.053)	(0.051)	(0.069)
Public clients	-0.039	0.037	-0.028	-0.042	0.023
	(0.054)	(0.097)	(0.067)	(0.065)	(0.111)
Competitors	0.096*	0.009	0.137**	0.096	0.159
	(0.053)	(0.099)	(0.063)	(0.060)	(0.129)
Consultants, private R&D	0.010	-0.041	0.005	0.003	0.035
	(0.045)	(0.082)	(0.056)	(0.054)	(0.078)
Universities, HEI	0.016	0.057	-0.017	0.004	0.029
	(0.042)	(0.072)	(0.060)	(0.050)	(0.085)
Government	-0.007	0.016	-0.009	0.013	-0.033
	(0.055)	(0.092)	(0.079)	(0.063)	(0.120)
Sector fixed effects	Yes	No	No	Yes	Yes
N	2763	854	1827	2137	626
Pseudo R2	0.230	0.256	0.176	0.218	0.298
Chi2	697.3	265.6	345.3	495.8	212.8

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 3: Determinants of green innovations – green innovations with benefits for the end user

Dep. Var.: Innovation with environmental benefits for the end user 2012-2014	All firms	Manufacturing	Services	Indigenous	Foreign-owned
Environmental regulations					
Pre-2012	0.082*** (0.019)	0.011 (0.035)	0.121*** (0.023)	0.080*** (0.022)	0.098*** (0.036)
Post-2012	0.177*** (0.018)	0.222*** (0.032)	0.163*** (0.023)	0.190*** (0.021)	0.146*** (0.037)
Innovation inputs					
Inhouse R&D	0.058** (0.023)	0.072* (0.040)	0.040 (0.028)	0.054** (0.026)	0.065 (0.045)
External R&D	0.016 (0.025)	0.062 (0.045)	-0.012 (0.032)	0.009 (0.031)	0.032 (0.046)
Machinery, equipment, software & buildings	0.073*** (0.020)	0.058 (0.038)	0.086*** (0.024)	0.092*** (0.022)	0.013 (0.044)
Other external knowledge	0.063*** (0.024)	0.059 (0.043)	0.049 (0.030)	0.071** (0.028)	0.024 (0.051)
Other innovation activities	0.011 (0.026)	0.034 (0.045)	-0.002 (0.034)	0.008 (0.031)	0.029 (0.049)
Firm-specific factors					
Productivity 2012	-0.001 (0.002)	-0.003 (0.006)	0.001 (0.003)	-0.000 (0.003)	-0.004 (0.005)
Size (employment quartile)	0.014* (0.008)	0.024 (0.016)	0.008 (0.009)	0.022*** (0.009)	-0.019 (0.019)
Exported to Europe	-0.024 (0.019)	-0.098** (0.041)	-0.001 (0.021)	-0.042** (0.021)	0.036 (0.047)
Exported to other destinations	-0.014 (0.020)	-0.029 (0.036)	-0.007 (0.024)	-0.009 (0.023)	0.007 (0.040)
Ownership					
Indigenous firm	0.062*** (0.022)	0.117*** (0.043)	0.046* (0.025)		
USA ownership					-0.032 (0.040)
EU ownership					0.016 (0.041)
Spillovers (innovations with benefits for the end user, industry level)	-0.168 (0.125)	-0.034 (0.165)	0.467*** (0.161)	-0.153 (0.143)	-0.169 (0.269)
Public funding					
Local/Regional authorities	0.017 (0.040)	-0.017 (0.063)	0.069 (0.054)	0.007 (0.045)	0.053 (0.103)
Central government	0.015 (0.027)	0.056 (0.042)	-0.041 (0.038)	0.021 (0.031)	0.003 (0.053)
European Union	0.068 (0.052)	0.153* (0.078)	-0.033 (0.084)	0.073 (0.056)	0.060 (0.120)
Co-operation partners					
Enterprise group	0.090*** (0.035)	0.123* (0.067)	0.084** (0.041)	0.100** (0.047)	0.053 (0.054)

Suppliers	-0.036 (0.037)	-0.027 (0.066)	-0.011 (0.044)	-0.089* (0.046)	0.082 (0.065)
Private clients	0.058 (0.041)	0.138* (0.072)	-0.047 (0.053)	0.090* (0.051)	0.014 (0.066)
Public clients	0.020 (0.053)	-0.057 (0.093)	0.088 (0.067)	0.041 (0.065)	-0.039 (0.095)
Competitors	0.166*** (0.050)	0.193** (0.091)	0.150** (0.063)	0.165*** (0.059)	0.197* (0.104)
Consultants, private R&D	-0.018 (0.043)	-0.102 (0.076)	0.033 (0.054)	-0.028 (0.053)	0.012 (0.071)
Universities, HEI	-0.032 (0.040)	-0.008 (0.069)	-0.060 (0.056)	-0.030 (0.048)	-0.018 (0.071)
Government	-0.042 (0.050)	-0.028 (0.079)	-0.028 (0.073)	-0.082 (0.060)	0.045 (0.096)
Sector fixed effects	Yes	No	No	Yes	Yes
N	2763	854	1827	2137	624
Pseudo R2	0.162	0.166	0.134	0.167	0.180
Chi2	487.5	168.7	252.5	384.5	127.8

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

5.3 Green innovations by environmental impact type

Tables 4-8 report results on determinants of green innovations by environmental impact type. To facilitate the discussion of the main results, Tables 4a-8a summarise the key estimates while Tables 4b-8b show the full set of estimates. In the case of green innovations with within firms benefits, the following types of environmental impacts are distinguished: reduced material or water use per unit of output; reduced energy use or CO₂ footprint (reduced CO₂ production); reduced air, water, noise or soil pollution; replaced a share of materials with less polluting or hazardous substitutes; replaced a share of fossil energy with renewable energy sources; recycled waste, water, or materials for own or sale. Environmental benefits obtained during the consumption or use of a good or service by the end user include: reduced energy use or CO₂ footprint; reduced air, water, noise or soil pollution; facilitated recycling of product after use; extended product life through longer-lasting, more durable products.

A key finding from the results reported in Tables 4-8 is the strong effect of environmental regulations on the introduction of all types of green innovations across all firms as well as for each of the groups of firms considered. The effects appear to be larger in the case of contemporaneous environmental regulations, with the largest effects in the case of green innovations with within firm benefits in terms of reduced energy use or CO₂ footprint (21.0 percentage points), recycled waste, water or materials (15.2 percentage points). Regulations are also an important driver of green innovations with benefits for the end user, the largest effects in the case of reduced energy use, or CO₂ footprint (15.1 percentage points).

Another important driver of green innovations with all types of environmental impacts is acquisition of capital assets with significant effects across all firms and in particular for firms in services and for indigenous firms. The average effects across all firms range from 6.1 percentage points (green innovations with within firm benefits in the area of reduced energy use of CO₂ footprint) to 2.3

percentage points (green innovations with within firm benefits in the area of renewable energy sources). In the case of services firms, the largest effect is 6.7 percentage points (green innovations with benefits for the final user in the area of facilitated recycling after use) and the lowest 1.8 percentage points (green innovations with within firm benefits in the area of renewable energy sources). In the case of manufacturing firms, the only significant effects are for green innovations with within firm benefits in the areas of recycled waste, water or materials (8.0 percentage points) and reduced energy use or CO₂ footprint (7.3 percentage points) and for green innovations with benefits for the final user in the area of reduced air, water, noise, or soil pollution (6.8 percentage points). Investment of capital assets is an important driver of green innovations introduced by indigenous firms in all environmental impact areas with the exception of green innovations with within firm benefits in the area of renewable energy sources. The largest effect is for green innovations with benefits for the final user in the area of facilitated recycling after use (6.9 percentage points) and the lowest for green innovations in the area of less green innovations with within firm benefits in the area of polluting or hazardous substitutes (3.5 percentage points). In the case of foreign-owned firms, investment in capital assets is a driver of green innovations only in the case of green innovations with within firm benefits in the areas of reduced material or water use (6.1 percentage points) and renewable energy sources (6.7 percentage points).

Public funding from the European Union is found positively and significantly associated with green innovations with benefits for the end user in the area of more durable products: on average, across all firms, having received funding from the European Union increases the propensity of firms to introduce green innovations in this area by 10.4 percentage points. Across all manufacturing firms the effect of EU funding is 8.4 percentage points, while the average effect across all indigenous firms is 10.9 percentage points. The effect is not significant in the case of firms in services and foreign-owned firms.

Table 4a: Determinants of green innovations by type of environmental benefits and environmental impact area – all firms, summary of results

Dependent Variable	Innovation with environmental benefits within the enterprise						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	+	+	+	+	+	+	+	+	+	+
Post-2012	+	+	+	+	+	+	+	+	+	+
Innovation inputs										
Inhouse R&D	+	+	0	+	0	0	+	+	0	+
External R&D	0	0	0	0	-	0	0	0	+	0
Machinery, equipment, software & buildings	+	+	+	+	+	+	+	+	+	+
Other external knowledge	0	0	0	0	0	0	0	0	+	+
Other innovation activities	0	0	+	+	+	+	0	0	0	+
Firm-specific factors										
Productivity 2012	0	0	0	0	0	0	0	0	0	0
Size (employment quartile)	+	+	+	+	+	+	+	+	0	0
Exported to Europe	0	0	0	0	0	0	0	0	0	0
Exported to other destinations	0	0	-	0	0	0	0	-	0	0
Spillovers (industry level)	0	0	0	0	0	0	0	0	-	0
Public funding										
Local/Regional authorities	0	0	0	0	0	0	0	0	0	0
Central government	0	0	0	0	0	0	0	0	0	0
European Union	0	0	0	0	0	0	0	0	0	+
Ownership										
Indigenous firm	0	0	0	0	0	0	+	+	+	0
Co-operation partners										
Enterprise group	0	0	+	+	0	0	+	+	+	+
Suppliers	0	0	0	0	0	0	0	0	0	0
Private clients	0	0	0	0	0	+	0	0	+	0
Public clients	+	0	0	0	0	0	0	0	0	0
Competitors	0	+	+	0	0	0	+	0	+	+
Consultants, private R&D	0	0	0	0	0	0	0	-	0	0
Universities, HEI	0	0	0	0	0	0	0	0	0	0
Government	0	+	0	0	+	0	0	+	0	-
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2763	2763	2763	2763	2763	2763	2763	2763	2763	2763
Pseudo R2	0.229	0.236	0.248	0.242	0.218	0.182	0.171	0.208	0.118	0.19
Chi2	518.3	621.6	508.7	410.6	290.8	450.8	417.7	361.6	301.9	363.5

Source: Authors' estimates based on data from the CSO.

Table 4b: Determinants of green innovations – by type of environmental benefits and environmental impact area – all firms

Dependent Variable	Innovation with environmental benefits within the firm						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	0.059*** (0.014)	0.058*** (0.016)	0.043*** (0.013)	0.044*** (0.012)	0.041*** (0.010)	0.065*** (0.016)	0.059*** (0.016)	0.038*** (0.012)	0.043** (0.017)	0.041*** (0.013)
Post-2012	0.138*** (0.014)	0.210*** (0.015)	0.148*** (0.013)	0.106*** (0.012)	0.061*** (0.010)	0.152*** (0.016)	0.151*** (0.015)	0.101*** (0.013)	0.136*** (0.017)	0.096*** (0.013)
Innovation inputs										
Inhouse R&D	0.048*** (0.018)	0.071*** (0.020)	0.018 (0.017)	0.037** (0.015)	0.010 (0.012)	0.021 (0.021)	0.061*** (0.019)	0.039*** (0.015)	-0.019 (0.021)	0.068*** (0.016)
External R&D	0.004 (0.019)	-0.019 (0.022)	0.014 (0.018)	0.000 (0.016)	-0.028** (0.013)	0.007 (0.022)	0.027 (0.020)	0.011 (0.016)	0.049** (0.023)	-0.005 (0.016)
Machinery, equipment, software & buildings	0.042** (0.017)	0.061*** (0.018)	0.038** (0.015)	0.031** (0.014)	0.023** (0.011)	0.056*** (0.018)	0.035** (0.017)	0.037*** (0.014)	0.050*** (0.018)	0.035** (0.014)
Other external knowledge	0.004 (0.019)	0.021 (0.021)	0.007 (0.018)	0.002 (0.016)	0.005 (0.013)	0.014 (0.022)	0.011 (0.019)	0.014 (0.016)	0.061*** (0.022)	0.037** (0.016)
Other innovation activities	0.016 (0.020)	0.028 (0.022)	0.032* (0.019)	0.040*** (0.015)	0.034*** (0.013)	0.045** (0.023)	0.008 (0.020)	0.016 (0.016)	0.011 (0.023)	0.027* (0.016)
Firm-specific factors										
Productivity 2012	0.001 (0.002)	-0.001 (0.002)	0.002 (0.002)	0.000 (0.002)	-0.000 (0.002)	-0.001 (0.002)	0.000 (0.002)	0.001 (0.002)	-0.000 (0.002)	-0.002 (0.002)
Size (employment quartile)	0.017*** (0.006)	0.035*** (0.007)	0.022*** (0.006)	0.009* (0.005)	0.012*** (0.004)	0.020*** (0.007)	0.015** (0.007)	0.018*** (0.006)	0.005 (0.007)	-0.006 (0.006)

Exported to Europe	-0.005 (0.016)	-0.001 (0.017)	-0.015 (0.015)	-0.010 (0.014)	-0.003 (0.011)	-0.004 (0.017)	0.000 (0.016)	-0.010 (0.013)	-0.006 (0.017)	0.001 (0.014)
Exported to other destinations	-0.015 (0.016)	-0.014 (0.018)	-0.035** (0.015)	-0.008 (0.013)	-0.010 (0.011)	-0.021 (0.018)	-0.020 (0.017)	-0.039*** (0.014)	-0.012 (0.018)	-0.010 (0.014)
Ownership										
Indigenous firm	0.001 (0.017)	-0.008 (0.018)	-0.000 (0.016)	0.008 (0.014)	-0.014 (0.010)	0.008 (0.018)	0.033* (0.018)	0.034** (0.015)	0.032* (0.019)	0.020 (0.016)
Spillovers (industry level)	0.074 (0.082)	-0.086 (0.093)	-0.024 (0.075)	-0.023 (0.064)	0.040 (0.056)	0.054 (0.091)	-0.086 (0.107)	-0.101 (0.085)	-0.305*** (0.108)	-0.081 (0.088)
Public funding										
Local/Regional authorities	0.019 (0.029)	0.006 (0.034)	0.006 (0.028)	0.023 (0.023)	0.004 (0.020)	-0.041 (0.034)	0.006 (0.032)	0.015 (0.024)	-0.010 (0.035)	0.018 (0.025)
Central government	0.010 (0.020)	-0.013 (0.023)	0.009 (0.019)	0.015 (0.016)	0.020 (0.013)	0.003 (0.023)	-0.005 (0.021)	0.001 (0.017)	-0.003 (0.024)	0.007 (0.017)
European Union	0.011 (0.039)	0.028 (0.044)	0.004 (0.035)	-0.013 (0.031)	-0.011 (0.027)	-0.015 (0.045)	0.034 (0.042)	-0.007 (0.034)	-0.035 (0.050)	0.104*** (0.032)
Co-operation partners										
Enterprise group	0.026 (0.025)	0.024 (0.030)	0.052** (0.023)	0.045** (0.019)	0.020 (0.015)	0.021 (0.030)	0.053** (0.027)	0.067*** (0.020)	0.079*** (0.029)	0.048** (0.021)
Suppliers	0.036 (0.026)	-0.001 (0.030)	-0.014 (0.025)	0.001 (0.022)	-0.001 (0.017)	0.014 (0.031)	-0.012 (0.028)	-0.007 (0.023)	-0.046 (0.031)	-0.022 (0.023)
Private clients	0.044 (0.028)	0.002 (0.033)	0.028 (0.027)	0.014 (0.022)	-0.015 (0.019)	0.083** (0.033)	0.007 (0.031)	0.019 (0.024)	0.057* (0.034)	0.018 (0.025)
Public clients	0.063* (0.035)	-0.035 (0.045)	0.034 (0.032)	0.011 (0.028)	0.004 (0.022)	0.065 (0.044)	-0.014 (0.040)	0.017 (0.029)	0.028 (0.045)	0.049 (0.031)
Competitors	-0.013 (0.036)	0.090** (0.041)	0.051* (0.030)	0.040 (0.027)	0.026 (0.021)	0.013 (0.042)	0.095** (0.037)	0.044 (0.028)	0.105** (0.042)	0.058** (0.029)
Consultants, private R&D	-0.020 (0.030)	-0.011 (0.035)	-0.012 (0.028)	0.005 (0.025)	-0.008 (0.018)	0.005 (0.036)	0.006 (0.032)	-0.049* (0.025)	-0.046 (0.036)	-0.011 (0.025)
Universities, HEI	0.034	0.037	-0.015	-0.023	0.012	-0.024	0.003	-0.024	-0.011	-0.026

	(0.028)	(0.032)	(0.027)	(0.023)	(0.018)	(0.035)	(0.031)	(0.024)	(0.034)	(0.024)
Government	0.012	0.082*	0.035	0.037	0.055***	0.023	0.035	0.049*	0.011	-0.082***
	(0.034)	(0.044)	(0.032)	(0.027)	(0.020)	(0.043)	(0.038)	(0.029)	(0.043)	(0.031)
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2763	2763	2763	2763	2763	2763	2763	2763	2763	2763
Pseudo R2	0.229	0.236	0.248	0.242	0.218	0.182	0.171	0.208	0.118	0.190
Chi2	518.3	621.6	508.7	410.6	290.8	450.8	417.7	361.6	301.9	363.5

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 5a: Determinants of green innovations by type of environmental benefits and environmental impact area – manufacturing firms, summary of results

Dependent Variable	Innovation with environmental benefits within the enterprise						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	0	0	0	0	+	0	0	0	0	0
Post-2012	+	+	+	+	+	+	+	+	+	+
Innovation inputs										
Inhouse R&D	0	+	0	0	0	0	+	+	0	+
External R&D	0	0	0	0	0	0	+	0	+	0
Machinery, equipment, software & buildings	0	+	0	0	0	+	0	+	0	0
Other external knowledge	0	0	0	0	0	0	0	0	+	+
Other innovation activities	0	0	0	0	0	+	0	0	0	+
Firm-specific factors										
Productivity 2012	0	0	0	0	0	0	0	0	0	0
Size (employment quartile)	+	+	+	+	+	+	+	+	0	0
Exported to Europe	+	0	0	0	0	0	0	0	0	0
Exported to other destinations	0	0	0	0	0	0	0	0	0	0
Spillovers (industry level)	0	0	0	0	0	0	0	0	-	0
Public funding										
Local/Regional authorities	0	0	0	0	0	0	0	0	0	0
Central government	0	0	0	0	0	0	0	0	0	0
European Union	0	+	0	0	0	0	0	0	0	+
Ownership										
Indigenous firm	0	0	+	0	0	0	+	+	+	+
Co-operation partners										
Enterprise group	0	0	+	0	0	0	0	+	+	0
Suppliers	+	0	0	0	0	0	0	0	0	0
Private clients	0	0	0	0	0	+	0	0	+	0
Public clients	0	0	0	0	0	0	0	0	0	+
Competitors	0	0	+	0	+	0	0	0	0	0
Consultants, private R&D	0	0	0	0	0	0	0	0	0	0
Universities, HEI	0	+	0	0	0	0	0	0	0	0
Government	0	0	0	0	+	0	0	+	0	-
Sector fixed effects	No	No	No	No	No	No	No	No	No	No
N	854	854	854	854	854	854	854	854	854	854
Pseudo R2	0.234	0.253	0.2	0.205	0.23	0.181	0.154	0.152	0.107	0.169
Chi2	207.3	227.2	173.3	143.9	126.7	180.2	129.2	105.1	90.86	123.3

Source: Authors' estimates based on data from the CSO.

Table 5b: Determinants of green innovations – by type of environmental benefits and environmental impact area – manufacturing firms

Dependent Variable	Innovation with environmental benefits within the firm						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	0.046 (0.030)	0.035 (0.030)	0.029 (0.029)	0.026 (0.027)	0.060*** (0.019)	0.033 (0.032)	-0.016 (0.031)	-0.029 (0.027)	-0.034 (0.033)	0.026 (0.028)
Post-2012	0.208*** (0.027)	0.246*** (0.025)	0.197*** (0.026)	0.148*** (0.025)	0.055*** (0.020)	0.217*** (0.029)	0.164*** (0.028)	0.119*** (0.026)	0.163*** (0.030)	0.100*** (0.027)
Innovation inputs										
Inhouse R&D	0.036 (0.038)	0.100*** (0.036)	0.027 (0.036)	0.047 (0.033)	-0.022 (0.025)	-0.048 (0.040)	0.089** (0.035)	0.062* (0.032)	-0.028 (0.039)	0.096*** (0.033)
External R&D	0.028 (0.039)	0.005 (0.039)	-0.011 (0.037)	0.015 (0.033)	0.010 (0.024)	0.030 (0.042)	0.073** (0.036)	0.018 (0.032)	0.095** (0.039)	-0.007 (0.032)
Machinery, equipment, software & buildings	0.055 (0.034)	0.073** (0.033)	0.054 (0.034)	0.040 (0.031)	0.019 (0.023)	0.080** (0.036)	0.007 (0.033)	0.068** (0.030)	0.008 (0.035)	0.015 (0.031)
Other external knowledge	-0.059 (0.039)	0.006 (0.037)	-0.006 (0.036)	0.015 (0.032)	-0.006 (0.025)	0.009 (0.040)	0.002 (0.035)	0.002 (0.031)	0.074* (0.038)	0.054* (0.032)
Other innovation activities	0.027 (0.038)	-0.027 (0.039)	0.003 (0.038)	0.043 (0.031)	0.035 (0.026)	0.100** (0.041)	0.033 (0.036)	0.025 (0.032)	0.004 (0.040)	0.053* (0.031)
Firm-specific factors										
Productivity 2012	0.003 (0.007)	0.000 (0.007)	0.009 (0.006)	0.006 (0.006)	-0.005 (0.004)	0.002 (0.006)	0.004 (0.006)	0.004 (0.005)	-0.003 (0.006)	-0.005 (0.005)
Size (employment quartile)	0.041*** (0.014)	0.056*** (0.015)	0.048*** (0.014)	0.033** (0.014)	0.035*** (0.011)	0.044*** (0.015)	0.026* (0.015)	0.027** (0.013)	0.013 (0.015)	0.003 (0.013)

Exported to Europe	0.086** (0.043)	0.028 (0.042)	0.035 (0.040)	-0.015 (0.038)	0.030 (0.031)	0.000 (0.041)	-0.055 (0.039)	-0.035 (0.035)	-0.063 (0.038)	-0.005 (0.036)
Exported to other destinations	0.008 (0.032)	-0.019 (0.032)	-0.028 (0.031)	0.033 (0.029)	-0.009 (0.021)	-0.036 (0.034)	0.001 (0.032)	-0.026 (0.029)	0.018 (0.033)	-0.012 (0.028)
Ownership										
Indigenous firm	0.049 (0.037)	0.008 (0.038)	0.058* (0.035)	0.034 (0.033)	0.013 (0.022)	0.039 (0.037)	0.073* (0.038)	0.069** (0.034)	0.089** (0.038)	0.084** (0.037)
Spillovers (industry level)	0.145 (0.128)	-0.020 (0.128)	-0.008 (0.120)	-0.041 (0.105)	0.081 (0.089)	0.126 (0.129)	0.022 (0.155)	-0.081 (0.139)	-0.246* (0.143)	-0.108 (0.132)
Public funding										
Local/Regional authorities	-0.006 (0.053)	-0.039 (0.053)	-0.007 (0.052)	0.065 (0.045)	0.003 (0.032)	-0.061 (0.058)	-0.000 (0.053)	0.048 (0.044)	0.030 (0.053)	-0.037 (0.049)
Central government	0.028 (0.037)	-0.025 (0.036)	0.039 (0.035)	0.0082 (0.032)	0.032 (0.023)	0.020 (0.039)	0.003 (0.034)	-0.000 (0.030)	0.010 (0.039)	0.023 (0.031)
European Union	0.024 (0.069)	0.107* (0.065)	-0.003 (0.063)	-0.022 (0.057)	-0.017 (0.041)	0.037 (0.070)	0.045 (0.060)	-0.029 (0.057)	0.032 (0.068)	0.168*** (0.053)
Co-operation partners										
Enterprise group	-0.031 (0.055)	0.021 (0.057)	0.131*** (0.050)	0.043 (0.044)	0.035 (0.030)	-0.033 (0.058)	0.045 (0.052)	0.104** (0.045)	0.109** (0.054)	0.070 (0.046)
Suppliers	0.102* (0.055)	0.054 (0.058)	-0.027 (0.051)	-0.010 (0.044)	-0.035 (0.030)	-0.009 (0.059)	0.003 (0.052)	-0.027 (0.046)	-0.009 (0.055)	-0.001 (0.046)
Private clients	0.086 (0.056)	-0.017 (0.060)	0.010 (0.057)	0.034 (0.045)	-0.012 (0.033)	0.192*** (0.063)	0.050 (0.054)	0.031 (0.048)	0.107* (0.057)	0.027 (0.048)
Public clients	0.137 (0.085)	-0.013 (0.082)	0.042 (0.072)	0.057 (0.063)	-0.002 (0.041)	0.115 (0.091)	-0.074 (0.074)	-0.030 (0.062)	0.046 (0.076)	0.111* (0.064)
Competitors	-0.049 (0.072)	-0.060 (0.069)	0.135** (0.066)	0.078 (0.059)	0.076** (0.037)	0.033 (0.079)	0.073 (0.070)	0.066 (0.058)	0.046 (0.073)	0.087 (0.060)
Consultants, private R&D	-0.005 (0.061)	-0.009 (0.064)	0.025 (0.056)	-0.023 (0.053)	-0.002 (0.032)	0.044 (0.067)	-0.001 (0.055)	-0.028 (0.051)	-0.101 (0.062)	0.009 (0.050)
Universities, HEI	0.089	0.107*	-0.056	0.017	-0.014	-0.010	0.028	-0.038	0.013	-0.064

	(0.054)	(0.056)	(0.050)	(0.045)	(0.033)	(0.062)	(0.052)	(0.045)	(0.057)	(0.044)
Government	-0.037	0.120	0.088	0.026	0.083**	0.009	0.059	0.120**	-0.029	-0.117**
	(0.064)	(0.073)	(0.060)	(0.052)	(0.033)	(0.074)	(0.060)	(0.052)	(0.068)	(0.055)
Sector fixed effects	No									
N	854	854	854	854	854	854	854	854	854	854
Pseudo R2	0.234	0.253	0.200	0.205	0.230	0.181	0.154	0.152	0.107	0.169
Chi2	207.3	227.2	173.3	143.9	126.7	180.2	129.2	105.1	90.86	123.3

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 6a: Determinants of green innovations by type of environmental benefits and environmental impact area – services firms, summary of results

Dependent Variable	Innovation with environmental benefits within the enterprise						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	+	+	+	+	+	+	+	+	+	+
Post-2012	+	+	+	+	+	+	+	+	+	+
Innovation inputs										
Internal R&D	+	+	0	0	0	+	+	0	0	+
External R&D	0	0	0	0	-	0	0	0	0	0
Machinery, equipment, software & buildings	+	+	+	+	0	+	+	+	+	+
Other external knowledge	+	0	0	0	0	0	0	0	0	+
Other innovation activities	0	+	+	+	+	0	0	0	0	0
Firm-specific factors										
Productivity 2012	0	0	0	0	0	0	0	0	0	0
Size (employment quartile)	0	+	0	0	0	0	0	+	0	0
Exported to Europe	-	0	-	0	0	0	0	0	0	0
Exported to other destinations	-	0	-	-	-	0	0	-	0	0
Spillovers (industry level)	+	+	+	+	0	+	0	+	0	+
Public funding										
Local/Regional authorities	0	0	0	0	0	0	0	0	0	+
Central government	0	0	0	0	0	0	0	0	0	0
European Union	0	0	0	0	0	-	0	0	-	0
Ownership										
Indigenous firm	0	0	0	0	-	0	0	0	0	0
Co-operation partners										
Enterprise group	0	0	0	+	0	0	+	+	+	0
Suppliers	0	0	0	0	0	0	0	0	0	0
Private clients	0	0	0	0	0	0	0	0	0	0
Public clients	0	0	0	0	0	0	0	0	0	0
Competitors	0	+	0	0	0	0	+	0	+	0
Consultants, private R&D	0	0	0	0	0	0	0	-	0	0
Universities, HEI	0	0	0	-	0	0	0	0	0	0
Government	+	0	0	+	+	0	0	0	0	0
Sector fixed effects	No	No	No	No	No	No	No	No	No	No
N	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827
Pseudo R2	0.174	0.201	0.22	0.224	0.209	0.146	0.169	0.217	0.124	0.19
Chi2	224.7	331.5	247.7	202.8	156.9	209.6	260.7	227.3	193	205.1

Source: Authors' estimates based on data from the CSO.

Table 6b: Determinants of green innovations – by type of environmental benefits and environmental impact area – services firms

Dependent Variable	Innovation with environmental benefits within the firm						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	0.066*** (0.016)	0.072*** (0.019)	0.045*** (0.014)	0.048*** (0.013)	0.024** (0.011)	0.088*** (0.019)	0.086*** (0.018)	0.056*** (0.013)	0.083*** (0.020)	0.047*** (0.015)
Post-2012	0.100*** (0.017)	0.202*** (0.018)	0.120*** (0.014)	0.086*** (0.013)	0.065*** (0.012)	0.130*** (0.019)	0.150*** (0.018)	0.091*** (0.014)	0.129*** (0.020)	0.095*** (0.015)
Innovation inputs										
Inhouse R&D	0.047** (0.019)	0.051** (0.024)	0.004 (0.018)	0.025 (0.016)	0.019 (0.013)	0.055** (0.023)	0.047** (0.022)	0.017 (0.015)	-0.024 (0.025)	0.046*** (0.017)
External R&D	-0.010 (0.022)	-0.047* (0.027)	0.018 (0.020)	-0.024 (0.018)	-0.047*** (0.016)	-0.018 (0.027)	-0.014 (0.025)	0.007 (0.018)	0.017 (0.028)	-0.002 (0.019)
Machinery, equipment, software & buildings	0.044** (0.018)	0.064*** (0.021)	0.033** (0.016)	0.035*** (0.013)	0.018 (0.012)	0.047** (0.021)	0.051*** (0.020)	0.031** (0.015)	0.067*** (0.021)	0.045*** (0.015)
Other external knowledge	0.038* (0.021)	0.030 (0.026)	0.012 (0.020)	-0.008 (0.017)	0.012 (0.015)	0.021 (0.026)	0.007 (0.024)	0.010 (0.018)	0.038 (0.027)	0.030* (0.018)
Other innovation activities	0.0098 (0.022)	0.054** (0.027)	0.048** (0.020)	0.040** (0.017)	0.034** (0.014)	0.014 (0.028)	-0.006 (0.026)	0.009 (0.018)	0.020 (0.029)	0.015 (0.019)
Firm-specific factors										
Productivity 2012	0.002 (0.002)	0.000 (0.002)	0.003 (0.002)	-0.000 (0.002)	0.002 (0.002)	0.000 (0.002)	0.000 (0.002)	0.002 (0.002)	0.002 (0.002)	0.001 (0.002)
Size (employment quartile)	0.007 (0.007)	0.024*** (0.008)	0.010 (0.006)	0.001 (0.005)	0.002 (0.005)	0.009 (0.008)	0.010 (0.007)	0.015*** (0.006)	0.004 (0.008)	-0.007 (0.006)
Exported to Europe	-0.029* (0.011)	-0.014 (0.011)	-0.026* (0.011)	-0.004 (0.011)	-0.007 (0.011)	-0.008 (0.011)	0.016 (0.011)	-0.005 (0.011)	0.010 (0.011)	-0.000 (0.011)

	(0.016)	(0.018)	(0.014)	(0.013)	(0.011)	(0.018)	(0.017)	(0.013)	(0.019)	(0.015)
Exported to other destinations	-0.033*	-0.016	-0.031*	-0.035**	-0.020*	-0.025	-0.025	-0.038***	-0.034	-0.010
	(0.018)	(0.021)	(0.016)	(0.015)	(0.011)	(0.021)	(0.019)	(0.014)	(0.022)	(0.015)
Ownership										
Indigenous firm	-0.016	-0.002	-0.018	0.008	-0.030***	0.008	0.023	0.020	0.023	-0.007
	(0.017)	(0.020)	(0.015)	(0.014)	(0.011)	(0.020)	(0.020)	(0.015)	(0.021)	(0.016)
Spillovers (industry level)										
	0.173*	0.330***	0.331***	0.167**	0.066	0.432***	0.149	0.405***	0.208	0.389***
	(0.102)	(0.120)	(0.093)	(0.077)	(0.070)	(0.119)	(0.131)	(0.111)	(0.142)	(0.119)
Public funding										
Local/Regional authorities	0.050	0.050	0.045	-0.019	0.017	-0.038	0.031	0.008	-0.044	0.055*
	(0.036)	(0.046)	(0.029)	(0.030)	(0.026)	(0.049)	(0.044)	(0.030)	(0.050)	(0.029)
Central government	-0.036	-0.039	-0.019	0.020	0.007	-0.052	-0.025	0.003	-0.018	-0.007
	(0.026)	(0.033)	(0.024)	(0.020)	(0.016)	(0.033)	(0.029)	(0.021)	(0.033)	(0.022)
European Union	-0.027	-0.034	0.007	-0.011	-0.039	-0.200**	0.017	-0.0006	-0.203**	0.067
	(0.054)	(0.073)	(0.049)	(0.044)	(0.038)	(0.082)	(0.066)	(0.050)	(0.084)	(0.047)
Co-operation partners										
Enterprise group	0.039	0.022	0.002	0.039**	0.014	0.037	0.069**	0.052**	0.081**	0.036
	(0.027)	(0.036)	(0.024)	(0.019)	(0.016)	(0.034)	(0.030)	(0.021)	(0.034)	(0.022)
Suppliers	0.026	-0.007	-0.005	0.016	0.024	0.038	-0.003	0.010	-0.025	-0.020
	(0.027)	(0.036)	(0.028)	(0.024)	(0.019)	(0.037)	(0.033)	(0.025)	(0.038)	(0.025)
Private clients	0.006	-0.001	0.029	-0.014	-0.027	-0.004	-0.065	-0.002	-0.036	-0.030
	(0.030)	(0.042)	(0.029)	(0.024)	(0.021)	(0.041)	(0.041)	(0.027)	(0.046)	(0.031)
Public clients	0.045	-0.029	0.032	-0.005	0.014	0.083	0.036	0.041	0.051	0.044
	(0.037)	(0.054)	(0.033)	(0.030)	(0.025)	(0.053)	(0.048)	(0.031)	(0.058)	(0.036)
Competitors	-0.014	0.163***	0.019	0.014	-0.007	0.017	0.119***	0.047	0.117**	0.054
	(0.040)	(0.048)	(0.035)	(0.029)	(0.026)	(0.053)	(0.045)	(0.029)	(0.052)	(0.034)
Consultants, private R&D	-0.038	-0.050	-0.031	0.032	-0.013	-0.036	0.003	-0.071***	-0.014	-0.019
	(0.035)	(0.046)	(0.031)	(0.026)	(0.021)	(0.047)	(0.041)	(0.027)	(0.047)	(0.030)
Universities, HEI	-0.021	-0.042	0.012	-0.054*	0.022	-0.028	-0.040	0.005	-0.017	0.002
	(0.035)	(0.046)	(0.033)	(0.030)	(0.023)	(0.050)	(0.044)	(0.029)	(0.050)	(0.032)
Government	0.079*	0.077	-0.003	0.067*	0.046*	0.066	0.030	-0.028	0.090	-0.060

	(0.043)	(0.062)	(0.041)	(0.037)	(0.028)	(0.062)	(0.055)	(0.039)	(0.064)	(0.041)
Sector fixed effects	No									
N	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827
Pseudo R2	0.174	0.201	0.220	0.224	0.209	0.146	0.169	0.217	0.124	0.190
Chi2	224.7	331.5	247.7	202.8	156.9	209.6	260.7	227.3	193.0	205.1

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 7a: Determinants of green innovations by type of environmental benefits and environmental impacts area – domestic firms, summary of results

Dependent Variable	Innovation with environmental benefits within the enterprise						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	+	+	0	+	+	+	+	+	0	+
Post-2012	+	+	+	+	+	+	+	+	+	+
Innovation inputs										
Inhouse R&D	+	+	0	0	0	0	+	+	0	+
External R&D	0	0	0	0	0	0	0	0	0	0
Machinery, equipment, software & buildings	+	+	+	+	0	+	+	+	+	+
Other external knowledge	0	0	0	0	0	0	0	0	+	+
Other innovation activities	0	0	0	+	+	0	0	0	0	+
Firm-specific factors										
Productivity 2012	0	0	0	0	0	0	0	0	0	0
Size (employment quartile)	+	+	+	+	+	+	+	+	0	0
Exported to Europe	0	0	0	0	0	0	0	0	0	0
Exported to other destinations	0	0	-	0	0	0	0	-	0	0
Environmental spillover (industry level)	0	0	0	0	0	0	0	0	-	-
Public funding										
Local/Regional authorities	0	0	0	0	0	0	0	0	0	0
Central government	0	0	0	0	0	0	0	0	0	0
European Union	0	0	0	0	0	0	0	0	0	+
Co-operation partners										
Enterprise group	0	0	0	0	0	0	+	+	+	+
Suppliers	0	0	0	0	0	0	0	0	-	0
Private clients	+	0	0	0	-	+	0	0	+	0
Public clients	+	0	0	0	0	0	0	0	0	0
Competitors	0	+	0	0	0	0	+	0	+	0
Consultants, private R&D	0	0	0	0	0	0	0	-	0	0
Universities, HEI	0	0	0	0	0	0	0	0	0	0
Government	0	0	0	0	0	0	0	0	0	-
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2137	2137	2137	2137	2137	2137	2137	2137	2137	2137
Pseudo R2	0.221	0.228	0.245	0.232	0.219	0.185	0.178	0.222	0.119	0.215
Chi2	378.7	460.7	367	288.7	208.7	350.8	327.6	291.7	238.1	313

Source: Authors' estimates based on data from the CSO.

Table 7b: Determinants of green innovations – by type of environmental benefits and environmental impacts area – indigenous firms

Dependent Variable	Innovation with environmental benefits within the firm						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Environmental regulations										
Pre-2012	0.048*** (0.016)	0.047** (0.018)	0.021 (0.015)	0.028** (0.013)	0.030*** (0.010)	0.063*** (0.019)	0.053*** (0.017)	0.028** (0.014)	0.027 (0.020)	0.035** (0.015)
Post-2012	0.142*** (0.016)	0.204*** (0.016)	0.148*** (0.014)	0.112*** (0.013)	0.054*** (0.011)	0.155*** (0.018)	0.149*** (0.017)	0.108*** (0.014)	0.150*** (0.019)	0.107*** (0.015)
Innovation inputs										
Inhouse R&D	0.040* (0.021)	0.069*** (0.023)	0.007 (0.019)	0.021 (0.017)	-0.015 (0.014)	0.010 (0.024)	0.056*** (0.021)	0.038** (0.017)	-0.022 (0.024)	0.052*** (0.018)
External R&D	0.016 (0.022)	-0.026 (0.025)	0.030 (0.021)	0.011 (0.019)	-0.016 (0.014)	0.030 (0.026)	0.013 (0.024)	0.013 (0.019)	0.044 (0.027)	0.006 (0.019)
Machinery, equipment, software & buildings	0.039** (0.019)	0.066*** (0.019)	0.044*** (0.017)	0.035** (0.015)	0.010 (0.012)	0.068*** (0.020)	0.058*** (0.019)	0.056*** (0.016)	0.069*** (0.020)	0.038** (0.016)
Other external knowledge	0.014 (0.022)	0.038 (0.023)	0.016 (0.020)	-0.000 (0.017)	0.017 (0.014)	0.012 (0.024)	0.017 (0.022)	0.018 (0.018)	0.063** (0.025)	0.037** (0.018)
Other innovation activities	0.016 (0.022)	0.024 (0.025)	0.035 (0.022)	0.045*** (0.017)	0.042*** (0.014)	0.039 (0.027)	0.009 (0.024)	0.016 (0.019)	0.019 (0.027)	0.048*** (0.018)
Firm-specific factors										
Productivity 2012	0.009 (0.002)	-0.003 (0.002)	0.002 (0.002)	-0.000 (0.002)	0.001 (0.002)	-0.001 (0.003)	0.001 (0.002)	0.002 (0.002)	0.001 (0.003)	-0.002 (0.002)
Size (employment quartile)	0.019***	0.039***	0.024***	0.010*	0.012**	0.014*	0.023***	0.022***	0.005	-0.002

	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)	(0.008)	(0.007)	(0.006)	(0.008)	(0.006)
Exported to Europe	-0.002	-0.007	-0.009	-0.010	0.004	-0.005	-0.009	-0.012	-0.015	-0.013
	(0.017)	(0.018)	(0.016)	(0.015)	(0.011)	(0.019)	(0.018)	(0.015)	(0.019)	(0.016)
Exported to other destinations	-0.009	-0.010	-0.039**	-0.010	-0.014	-0.033	-0.013	-0.041***	-0.008	-0.013
	(0.018)	(0.020)	(0.017)	(0.015)	(0.011)	(0.021)	(0.019)	(0.016)	(0.021)	(0.016)
Spillovers (industry level)	0.053	-0.022	0.012	-0.008	0.025	-0.034	-0.087	-0.096	-0.25**	-0.17*
	(0.095)	(0.11)	(0.087)	(0.074)	(0.060)	(0.103)	(0.123)	(0.102)	(0.125)	(0.098)
Public funding										
Local/Regional authorities	0.017	-0.025	0.004	0.008	0.014	-0.040	-0.017	0.018	-0.021	0.024
	(0.031)	(0.038)	(0.029)	(0.024)	(0.018)	(0.037)	(0.035)	(0.026)	(0.037)	(0.026)
Central government	0.011	-0.021	0.001	0.017	0.024*	-0.014	-0.010	-0.006	-0.006	0.014
	(0.022)	(0.026)	(0.021)	(0.019)	(0.014)	(0.027)	(0.024)	(0.019)	(0.028)	(0.019)
European Union	0.021	0.009	-0.007	-0.020	-0.005	0.006	0.007	-0.034	-0.036	0.109***
	(0.040)	(0.047)	(0.039)	(0.033)	(0.027)	(0.050)	(0.046)	(0.040)	(0.057)	(0.034)
Co-operation partners										
Enterprise group	0.001	-0.022	0.027	0.013	-0.007	-0.025	0.070**	0.075***	0.072*	0.062**
	(0.031)	(0.038)	(0.028)	(0.024)	(0.017)	(0.040)	(0.034)	(0.025)	(0.039)	(0.027)
Suppliers	0.010	-0.014	-0.003	-0.019	-0.013	0.017	-0.038	-0.024	-0.102***	-0.034
	(0.030)	(0.034)	(0.029)	(0.027)	(0.019)	(0.038)	(0.035)	(0.030)	(0.039)	(0.028)
Private clients	0.069**	0.005	0.046	0.015	-0.040*	0.114***	0.004	0.019	0.106**	0.041
	(0.033)	(0.040)	(0.033)	(0.026)	(0.023)	(0.041)	(0.039)	(0.031)	(0.042)	(0.031)
Public clients	0.085**	-0.017	0.032	0.020	0.042*	0.062	0.011	0.043	0.020	0.026
	(0.040)	(0.053)	(0.037)	(0.032)	(0.024)	(0.051)	(0.048)	(0.036)	(0.054)	(0.037)
Competitors	-0.011	0.085*	0.031	0.041	0.032	0.024	0.092**	0.036	0.105**	0.025
	(0.039)	(0.047)	(0.035)	(0.031)	(0.023)	(0.048)	(0.042)	(0.032)	(0.048)	(0.034)
Consultants, private R&D	-0.029	0.031	-0.023	0.031	0.016	-0.020	0.027	-0.074***	-0.052	-0.017
	(0.032)	(0.040)	(0.032)	(0.028)	(0.020)	(0.043)	(0.038)	(0.028)	(0.042)	(0.029)
Universities, HEI	0.019	0.035	-0.033	-0.015	0.026	-0.010	0.026	-0.007	0.006	-0.010
	(0.032)	(0.038)	(0.032)	(0.027)	(0.019)	(0.043)	(0.036)	(0.029)	(0.041)	(0.028)
Government	0.005	0.067	0.042	0.035	0.030	0.060	-0.017	0.032	-0.003	-0.107***

	(0.038)	(0.049)	(0.037)	(0.032)	(0.021)	(0.050)	(0.044)	(0.035)	(0.052)	(0.036)
Sector fixed effects	Yes									
N	2137	2137	2137	2137	2137	2137	2137	2137	2137	2137
Pseudo R2	0.221	0.228	0.245	0.232	0.219	0.185	0.178	0.222	0.119	0.215
Chi2	378.7	460.7	367.0	288.7	208.7	350.8	327.6	291.7	238.1	313.0

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 8a: Determinants of green innovations by type of environmental benefits and environmental impact area, foreign-owned firms, summary of results

Dependent Variable	Innovation with environmental benefits within the enterprise						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Regulation procedures										
Pre-2012	+	+	+	+	+	+	+	+	+	+
Post-2012	+	+	+	+	+	+	+	+	+	+
Innovation inputs										
Inhouse R&D	0	0	0	+	+	0	+	0	0	+
External R&D	0	0	0	0	-	0	0	0	0	0
Machinery, equipment, software & buildings	+	0	0	0	+	0	0	0	0	0
Other external knowledge	0	0	0	0	0	0	0	0	0	0
Other innovation activities	0	0	0	0	0	0	0	0	0	0
Firm-specific factors										
Productivity 2012	0	0	0	0	0	0	0	0	0	0
Size (employment quartile)	0	0	0	0	0	+	0	0	0	0
Exported to Europe	0	0	0	0	-	0	0	0	0	0
Exported to other destinations	0	0	0	0	0	0	0	0	0	0
Environmental spillover (industry level)	0	0	0	0	0	+	0	0	-	0
Public funding										
Local/Regional authorities	0	+	0	0	0	0	0	0	0	0
Central government	0	0	0	0	0	0	0	0	0	0
European Union	0	0	0	0	0	0	0	0	0	0
Ownership										
USA ownership	0	-	0	0	0	0	-	0	0	0
EU ownership	0	0	0	0	+	0	0	0	0	0
Co-operation partners										
Enterprise group	0	+	+	+	+	+	0	0	+	0
Suppliers	+	0	0	0	0	0	0	0	0	0
Private clients	0	0	0	0	0	0	0	0	0	-
Public clients	0	0	0	0	-	0	0	0	0	+
Competitors	0	0	0	0	0	0	0	0	0	+
Consultants, private R&D	0	0	0	0	0	0	0	0	0	0
Universities, HEI	0	0	0	0	0	0	0	0	0	0
Government	0	0	0	0	+	0	+	0	0	0
Sector fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
N	620	626	623	624	620	626	626	623	624	621
Pseudo R2	0.259	0.293	0.29	0.303	0.293	0.207	0.205	0.248	0.154	0.187
Chi2	168.7	201.1	155	138.2	126.5	131.3	127.4	115	91.07	99.55

Source: Authors' estimates based on data from the CSO.

Table 8b: Determinants of green innovations – by type of environmental benefits and environmental impact area– foreign-owned firms

Dependent Variable	Innovation with environmental benefits within the firm						Innovation with environmental benefits for the end user			
	Reduced material or water use	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Less polluting or hazardous substitutes	Renewable energy sources	Recycled waste, water or materials	Reduced energy use or CO2 footprint	Reduced air, water, noise or soil pollution	Facilitated recycling after use	More durable products
Regulation procedures										
Pre-2012	0.099*** (0.030)	0.107*** (0.032)	0.110*** (0.029)	0.103*** (0.026)	0.085*** (0.026)	0.079** (0.034)	0.082** (0.033)	0.070*** (0.026)	0.094*** (0.033)	0.061** (0.028)
Post-2012	0.124*** (0.032)	0.226*** (0.031)	0.150*** (0.028)	0.090*** (0.026)	0.087*** (0.026)	0.153*** (0.033)	0.165*** (0.032)	0.080*** (0.027)	0.110*** (0.034)	0.063** (0.030)
Innovation inputs										
Inhouse R&D	0.055 (0.038)	0.058 (0.042)	0.033 (0.035)	0.088*** (0.032)	0.067** (0.030)	0.033 (0.043)	0.071* (0.039)	0.015 (0.031)	-0.012 (0.041)	0.104*** (0.031)
External R&D	-0.034 (0.041)	-0.002 (0.044)	-0.019 (0.038)	-0.021 (0.032)	-0.063** (0.030)	-0.037 (0.043)	0.059 (0.039)	0.013 (0.032)	0.062 (0.042)	-0.024 (0.032)
Machinery, equipment, software & buildings	0.061* (0.036)	0.039 (0.038)	0.023 (0.034)	0.009 (0.029)	0.067** (0.028)	0.015 (0.039)	-0.052 (0.038)	-0.045 (0.029)	-0.021 (0.040)	0.033 (0.032)
Other external knowledge	-0.052 (0.043)	-0.019 (0.048)	-0.048 (0.041)	-0.002 (0.033)	-0.027 (0.029)	-0.004 (0.047)	0.004 (0.043)	0.001 (0.033)	0.034 (0.045)	0.018 (0.033)
Other innovation activities	0.033 (0.043)	0.060 (0.046)	0.032 (0.038)	0.028 (0.031)	0.019 (0.028)	0.063 (0.044)	0.010 (0.042)	0.032 (0.032)	-0.031 (0.045)	-0.021 (0.032)
Firm-specific factors										
Productivity 2012	0.002 (0.005)	0.008 (0.006)	0.007 (0.005)	0.001 (0.004)	-0.004 (0.009)	-0.001 (0.005)	-0.002 (0.004)	0.001 (0.003)	-0.007 (0.005)	-0.002 (0.004)
Size (employment quartile)	0.006 (0.016)	0.023 (0.018)	0.018 (0.016)	0.000 (0.015)	0.005 (0.012)	0.051*** (0.017)	-0.019 (0.017)	-0.000 (0.012)	0.007 (0.016)	-0.015 (0.013)
Exported to Europe	-0.029 (0.041)	0.018 (0.046)	-0.035 (0.038)	-0.002 (0.035)	-0.055* (0.031)	0.017 (0.047)	0.030 (0.042)	-0.007 (0.033)	0.040 (0.043)	0.043 (0.038)

Exported to other destinations	-0.020	-0.008	-0.027	-0.008	0.001	-0.005	-0.009	-0.012	-0.007	0.006
	(0.036)	(0.039)	(0.032)	(0.029)	(0.029)	(0.038)	(0.034)	(0.025)	(0.036)	(0.029)
Ownership										
USA ownership	-0.034	-0.083**	0.001	0.022	0.036	0.014	-0.057*	-0.033	-0.004	-0.007
	(0.035)	(0.037)	(0.032)	(0.030)	(0.027)	(0.037)	(0.035)	(0.027)	(0.036)	(0.028)
EU ownership	-0.017	0.032	-0.013	-0.012	0.051*	0.034	-0.003	-0.011	0.019	0.011
	(0.038)	(0.040)	(0.035)	(0.032)	(0.030)	(0.040)	(0.036)	(0.029)	(0.037)	(0.030)
Spillovers (industry level)	0.200	-0.223	-0.063	-0.071	0.068	0.337*	-0.121	-0.157	-0.509**	0.264
	(0.167)	(0.183)	(0.149)	(0.139)	(0.123)	(0.193)	(0.228)	(0.165)	(0.236)	(0.193)
Public funding										
Local/Regional authorities	0.007	0.184**	0.044	0.086	-0.043	-0.062	0.100	-0.010	-0.016	-0.038
	(0.085)	(0.087)	(0.076)	(0.061)	(0.070)	(0.095)	(0.092)	(0.078)	(0.094)	(0.086)
Central government	0.015	0.005	0.037	-0.001	0.021	0.044	0.011	0.036	0.007	-0.009
	(0.046)	(0.05)	(0.042)	(0.035)	(0.030)	(0.049)	(0.044)	(0.035)	(0.049)	(0.036)
European Union	-0.061	0.123	-0.012	0.007	-0.054	-0.093	0.146	0.070	-0.009	0.069
	(0.096)	(0.111)	(0.088)	(0.078)	(0.074)	(0.102)	(0.097)	(0.068)	(0.101)	(0.077)
Co-operation partners										
Enterprise group	0.037	0.103*	0.101**	0.081**	0.069**	0.095*	0.054	0.057	0.084*	0.052
	(0.050)	(0.056)	(0.040)	(0.034)	(0.031)	(0.049)	(0.047)	(0.036)	(0.049)	(0.036)
Suppliers	0.096*	-0.014	-0.030	0.044	0.007	-0.028	0.052	0.048	0.065	0.002
	(0.054)	(0.065)	(0.048)	(0.039)	(0.036)	(0.060)	(0.055)	(0.039)	(0.056)	(0.043)
Private clients	0.007	0.026	-0.016	0.018	0.007	0.014	0.014	0.043	-0.021	-0.083**
	(0.056)	(0.059)	(0.050)	(0.040)	(0.035)	(0.061)	(0.054)	(0.037)	(0.058)	(0.041)
Public clients	0.025	-0.092	0.051	-0.008	-0.103**	0.071	-0.086	-0.050	0.077	0.106*
	(0.078)	(0.087)	(0.071)	(0.058)	(0.051)	(0.094)	(0.077)	(0.055)	(0.079)	(0.059)
Competitors	0.005	0.128	0.085	0.065	0.032	0.026	0.108	0.078	0.104	0.132**
	(0.088)	(0.090)	(0.070)	(0.059)	(0.053)	(0.089)	(0.081)	(0.053)	(0.083)	(0.064)
Consultants, private R&D	0.009	-0.112	0.014	-0.034	-0.046	0.070	-0.044	0.000	-0.028	-0.009
	(0.062)	(0.071)	(0.056)	(0.052)	(0.040)	(0.065)	(0.060)	(0.045)	(0.063)	(0.051)
Universities, HEI	0.060	0.018	0.006	-0.041	-0.024	-0.050	-0.036	-0.070	-0.028	-0.049
	(0.058)	(0.067)	(0.052)	(0.044)	(0.040)	(0.064)	(0.061)	(0.043)	(0.061)	(0.045)
Government	0.050	0.144	0.044	0.045	0.159***	-0.022	0.132*	0.079	0.030	0.012
	(0.085)	(0.098)	(0.068)	(0.057)	(0.051)	(0.084)	(0.077)	(0.053)	(0.074)	(0.054)

Sector fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
N	620	626	623	624	620	626	626	623	624	621
Pseudo R2	0.259	0.293	0.290	0.303	0.293	0.207	0.205	0.248	0.154	0.187
Chi2	168.7	201.1	155.0	138.2	126.5	131.3	127.4	115.0	91.07	99.55

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

5.4 Additional co-variates

Tables 9-11 report results from regressions with additional co-variates. More specifically, the additional co-variates include: controls for green innovation persistence (a categorical variable that is equal to 1 for firms with green innovations over the period 2006-2008); wage per employee (a proxy for human capital); export intensity (export sales as a share of turnover); import intensity (import sales as a share of turnover); energy intensity (fuel consumption as a share of sales); market share (firm's turnover as a share of industry turnover). The indicator for green innovations introduced over the period 2006-2008 is constructed using data from the Community Innovation Survey 2008. The questions about innovations with environmental benefits have not been asked between 2008 and 2014. All continuous variables are lagged with respect to the dependent variable to avoid potential reverse causality. The information on these additional variables comes from the Census for Industrial Production and the Annual Services Inquiry for 2011.¹⁴ Given that not all firms are surveyed every time and, in every survey, the linked data set is more limited with respect to the number of year-firm observations. The sample for all firms includes 498 firm-year observations in comparison to 2,763 observations analysed on the basis of the CIS 2014. The subsamples corresponding to the different groups of firms are even more limited. Therefore, these results should be regarded as indicative only.

The key result from these additional regressions is on the persistence of green innovations. On average, across all firms, previous green innovators are more likely to introduce green innovations in the analysed period by 6.6 percentage points relative to firms with no green innovations before 2008. The persistence effect is positive and statistically significant for firms in services (20.7 percentage points) and foreign-owned firms (21.2 percentage points). The estimated persistence effects are weaker when the regressions are carried out separately for innovations with within firm environmental benefits and for innovations with environmental benefits for the final consumer. These effects are still significant (albeit only marginally) for firms in services and for foreign-owned firms.

¹⁴ These variables are lagged by one year with respect to the dependent variables to avoid reverse causality concerns.

Table 9: Determinants of green innovations - Additional co-variates

Dep. Var.: Innovation with environmental benefits 2012-2014	All firms	Manufacturing	Services	Indigenous	Foreign-owned
Persistence					
Dep. Var. 2006-2008	0.066*	-0.010	0.207***	0.039	0.212***
	(0.039)	(0.049)	(0.058)	(0.048)	(0.073)
Environmental regulations					
Pre-2012	0.042	-0.020	0.091	0.059	-0.013
	(0.041)	(0.046)	(0.073)	(0.051)	(0.070)
Post-2012	0.261***	0.240***	0.290***	0.277***	0.287***
	(0.039)	(0.044)	(0.073)	(0.049)	(0.070)
Innovation inputs					
In-house R&D	0.011	-0.098	0.107	0.059	-0.143
	(0.051)	(0.063)	(0.097)	(0.068)	(0.089)
External R&D	-0.002	0.069	-0.257*	0.026	-0.095
	(0.067)	(0.076)	(0.134)	(0.088)	(0.111)
Machinery, equipment, software & buildings	0.160***	0.247***	0.029	0.123**	0.192**
	(0.045)	(0.051)	(0.083)	(0.060)	(0.075)
Other external knowledge	0.007	-0.115	0.278**	0.056	-0.077
	(0.061)	(0.074)	(0.114)	(0.077)	(0.107)
Other innovation activities	0.052	0.082	0.157	0.073	0.067
	(0.065)	(0.070)	(0.126)	(0.080)	(0.107)
Firm-specific factors					
Productivity 2012	0.007	-0.008	0.015	0.009	0.014
	(0.007)	(0.011)	(0.011)	(0.009)	(0.014)
Size (employment quartile)	0.042*	0.059**	-0.012	0.059**	-0.048
	(0.022)	(0.026)	(0.036)	(0.026)	(0.047)
Exported to Europe	-0.016	-0.134**	0.032	-0.040	-0.071
	(0.051)	(0.069)	(0.077)	(0.055)	(0.100)
Exported to other destinations	-0.054	-0.048	-0.021	-0.129**	0.158*
	(0.045)	(0.048)	(0.082)	(0.057)	(0.082)
Wage per employee 2011	0.061	0.090*	-0.115	0.070	-0.023
	(0.048)	(0.054)	(0.084)	(0.052)	(0.103)
Export sales ratio 2011	0.104*	0.109*	0.047	0.119	0.191**
	(0.061)	(0.065)	(0.136)	(0.081)	(0.083)
Import sales ratio 2011	-0.092	1.785***	-0.067	0.004	-0.158
	(0.128)	(0.586)	(0.150)	(0.190)	(0.169)
Fuel sales ratio 2011	0.817*	0.540	0.585	1.063*	4.799
	(0.421)	(0.691)	(0.550)	(0.544)	(3.582)
Firm market share 2011	0.120	0.380**	-0.766	0.299	-0.199
	(0.153)	(0.164)	(0.487)	(0.240)	(0.193)
Ownership					
Indigenous firm	0.120***	0.156***	0.038		
	(0.046)	(0.050)	(0.07)		
USA ownership					-0.017
					(0.077)
EU ownership					-0.078
					(0.092)
Spillovers (industry level)	0.276	0.215	-0.300	0.307	0.320
	(0.187)	(0.179)	(0.563)	(0.240)	(0.281)
Public funding					

Local/Regional authorities	0.191*	0.268**	-0.108	0.209*	0.215
	(0.102)	(0.133)	(0.252)	(0.120)	(0.161)
Central government	0.109*	0.139**	-0.007	-0.012	0.273**
	(0.064)	(0.064)	(0.144)	(0.076)	(0.119)
European Union	0.022	-0.116		0.259*	-0.493***
	(0.132)	(0.115)		(0.142)	(0.166)
Co-operation partners					
Enterprise group	0.090	0.057		-0.128	0.193
	(0.115)	(0.128)		(0.157)	(0.158)
Suppliers	-0.002	-0.075		0.130	-0.202
	(0.149)	(0.150)		(0.164)	(0.188)
Private clients	0.043	0.201		0.100	0.101
	(0.101)	(0.126)		(0.130)	(0.172)
Public clients	0.292*	-0.050		0.186	
	(0.160)	(0.214)		(0.168)	
Competitors	0.148	0.031		0.175	
	(0.142)	(0.125)		(0.150)	
Consultants, private R&D	0.028	-0.016		-0.135	0.106
	(0.128)	(0.144)		(0.145)	(0.156)
Universities, HEI	-0.071	0.016		-0.066	0.210
	(0.117)	(0.130)		(0.145)	(0.182)
Government	-0.159	-0.038		-0.011	
	(0.148)	(0.187)		(0.169)	
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	No	No	Yes	Yes
N	498	281	184	344	143
Pseudo R2	0.294	0.398	0.266	0.313	0.444
Chi2	171.5	114.7	66.54	144.0	82.33

Source: Authors' estimates based on data from the CSO. Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 10: Determinants of green innovations with within firm benefits – Additional co-variates

Dep. Var.: Innovation with environmental benefits within the enterprise 2012-2014	All firms	Manufacturing	Services	Indigenous	Foreign-owned
Persistence					
Dep. Var. 2006-2008	0.045 (0.040)	-0.001 (0.051)	0.129** (0.058)	0.027 (0.050)	0.129* (0.072)
Environmental regulations					
Pre-2012	0.009 (0.042)	-0.052 (0.050)	0.022 (0.071)	-0.009 (0.055)	0.009 (0.070)
Post-2012	0.259*** (0.039)	0.248*** (0.047)	0.233*** (0.066)	0.265*** (0.051)	0.283*** (0.069)
Innovation inputs					
In-house R&D	0.013 (0.052)	-0.084 (0.064)	0.058 (0.088)	0.096 (0.070)	-0.144* (0.080)
External R&D	0.021 (0.066)	0.108 (0.081)	-0.255** (0.130)	0.048 (0.085)	-0.032 (0.111)
Machinery, equipment, software & buildings	0.140*** (0.045)	0.237*** (0.055)	0.018 (0.074)	0.107* (0.059)	0.141* (0.072)
Other external knowledge	-0.017 (0.061)	-0.130* (0.076)	0.275*** (0.101)	0.010 (0.077)	-0.026 (0.106)
Other innovation activities	0.009 (0.064)	0.027 (0.072)	0.161 (0.117)	-0.043 (0.084)	0.063 (0.100)
Firm-specific factors					
Productivity 2012	0.005 (0.008)	-0.003 (0.011)	0.005 (0.010)	0.003 (0.009)	0.021 (0.015)
Size (employment quartile)	0.049** (0.023)	0.048* (0.028)	0.019 (0.035)	0.067** (0.027)	0.008 (0.048)
Exported to Europe	-0.021 (0.051)	-0.086 (0.073)	0.002 (0.070)	-0.056 (0.060)	0.099 (0.103)
Exported to other destinations	-0.026 (0.045)	-0.022 (0.051)	0.021 (0.078)	-0.056 (0.058)	0.072 (0.080)
Wage per employee 2011	0.054 (0.048)	0.098 (0.063)	-0.175** (0.083)	0.065 (0.055)	-0.034 (0.108)
Export sales ratio 2011	0.097 (0.060)	0.081 (0.070)	0.013 (0.126)	0.049 (0.084)	0.227*** (0.082)
Import sales ratio 2011	-0.122 (0.132)	2.316*** (0.673)	-0.133 (0.154)	-0.169 (0.206)	-0.129 (0.173)
Fuel sales ratio 2011	0.666 (0.413)	0.746 (0.710)	-0.089 (0.500)	0.838 (0.569)	4.841 (3.477)
Firm market share 2011	0.046 (0.144)	0.137 (0.192)	-0.170 (0.260)	0.135 (0.248)	-0.044 (0.166)
Ownership					
Indigenous firm	0.105** (0.045)	0.143*** (0.054)	0.020 (0.067)		
USA ownership					0.009 (0.079)
EU ownership					-0.017 (0.088)

Spillovers (innovations with benefits within the enterprise, industry level)	0.178	0.076	0.268	0.153	0.160
	(0.185)	(0.185)	(0.510)	(0.255)	(0.263)
Public funding					
Local/Regional authorities	0.075	0.056	0.026	0.061	0.237
	(0.108)	(0.121)	(0.221)	(0.118)	(0.159)
Central government	0.128**	0.157**	0.117	0.029	0.316***
	(0.063)	(0.067)	(0.124)	(0.076)	(0.120)
European Union	-0.005	-0.120		0.169	-0.436***
	(0.130)	(0.124)		(0.157)	(0.161)
Co-operation partners					
Enterprise group	0.149	0.142	0.284	0.106	0.076
	(0.104)	(0.128)	(0.174)	(0.149)	(0.161)
Suppliers	-0.061	-0.068	-3.092***	0.041	-0.259*
	(0.127)	(0.148)	(0.362)	(0.186)	(0.150)
Private clients	0.045	0.146	-0.320*	0.022	0.149
	(0.095)	(0.121)	(0.194)	(0.133)	(0.135)
Public clients	-0.131	-0.035	-0.246	-0.251	
	(0.155)	(0.225)	(0.249)	(0.176)	
Competitors	0.324*	0.002		0.323**	
	(0.169)	(0.123)		(0.159)	
Consultants, private R&D	0.049	0.001	2.923***	0.030	0.055
	(0.115)	(0.139)	(0.300)	(0.166)	(0.155)
Universities, HEI	-0.022	0.032	1.593***	-0.087	0.301*
	(0.108)	(0.133)	(0.326)	(0.138)	(0.169)
Government	-0.022	0.015	-1.927***	0.043	
	(0.150)	(0.182)	(0.315)	(0.160)	
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	No	No	Yes	Yes
N	498	281	200	344	143
Pseudo R2	0.286	0.359	0.294	0.267	0.462
Chi2	174.7	108.9	1810.5	134.0	82.89

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

Table 11: Determinants of green innovations with benefits for the end user – Additional covariates

Dep. Var.: Innovation with environmental benefits for the end user 2012-2014	All firms	Manufacturing	Services	Indigenous	Foreign-owned
Persistence					
Dep. Var. 2006-2008	0.019 (0.042)	0.022 (0.055)	0.101* (0.060)	-0.038 (0.051)	0.138* (0.076)
Environmental regulations					
Pre-2012	0.069 (0.044)	-0.043 (0.058)	0.221*** (0.066)	0.114** (0.054)	-0.035 (0.074)
Post-2012	0.154*** (0.044)	0.157*** (0.059)	0.153** (0.075)	0.174*** (0.055)	0.217*** (0.081)
Innovation inputs					
In-house R&D	0.091 (0.056)	0.040 (0.073)	0.009 (0.098)	0.106 (0.074)	0.023 (0.092)
External R&D	0.049 (0.060)	0.140* (0.077)	-0.286** (0.111)	0.024 (0.083)	-0.045 (0.106)
Machinery, equipment, software & buildings	0.116** (0.049)	0.155** (0.063)	0.044 (0.078)	0.067 (0.062)	0.225*** (0.081)
Other external knowledge	0.029 (0.060)	-0.015 (0.077)	0.225** (0.107)	0.114 (0.079)	0.071 (0.105)
Other innovation activities	-0.023 (0.062)	0.032 (0.078)	0.123 (0.112)	-0.049 (0.082)	0.076 (0.099)
Firm-specific factors					
Productivity 2012	0.002 (0.008)	-0.018 (0.011)	0.010 (0.010)	-0.001 (0.009)	-0.005 (0.013)
Size (employment quartile)	0.042* (0.025)	0.066* (0.034)	-0.036 (0.036)	0.038 (0.029)	-0.016 (0.057)
Exported to Europe	-0.049 (0.057)	-0.216** (0.087)	-0.036 (0.074)	-0.027 (0.064)	-0.240** (0.115)
Exported to other destinations	-0.073 (0.049)	-0.097 (0.059)	-0.012 (0.081)	-0.131** (0.062)	0.133 (0.090)
Wage per employee 2011	0.003 (0.051)	0.057 (0.063)	-0.080 (0.085)	-0.005 (0.059)	-0.021 (0.118)
Export sales ratio 2011	0.076 (0.064)	0.138* (0.076)	-0.026 (0.111)	0.105 (0.089)	0.080 (0.097)
Import sales ratio 2011	-0.111 (0.139)	-0.102 (0.364)	0.019 (0.142)	0.100 (0.204)	-0.396** (0.192)
Fuel sales ratio 2011	0.525 (0.386)	0.476 (0.523)	0.229 (0.563)	0.187 (0.578)	1.138** (0.533)
Firm market share 2011	0.042 (0.165)	0.050 (0.214)	0.149 (0.248)	0.166 (0.265)	0.156 (0.215)
Ownership					
Indigenous firm	0.195*** (0.048)	0.238*** (0.064)	0.192*** (0.074)		
USA ownership					0.009 (0.084)
EU ownership					0.033 (0.087)

Spillovers (innovations with benefits for the end user, industry level)	-0.119	-0.287	-1.009	0.113	-0.506
	(0.238)	(0.269)	(0.709)	(0.316)	(0.363)
Public funding					
Local/Regional authorities	0.000	0.014	-0.086	0.037	0.022
	(0.101)	(0.114)	(0.247)	(0.110)	(0.196)
Central government	0.037	-0.011	0.126	-0.008	0.085
	(0.061)	(0.075)	(0.119)	(0.077)	(0.109)
European Union	0.132	-0.028		0.419**	
	(0.122)	(0.138)		(0.167)	
Co-operation partners					
Enterprise group	0.053	0.081	-0.092	0.079	-0.092
	(0.100)	(0.126)	(0.220)	(0.167)	(0.137)
Suppliers	0.024	-0.144		-0.028	0.264*
	(0.115)	(0.137)		(0.187)	(0.155)
Private clients	-0.008	0.227*		0.028	-0.241
	(0.099)	(0.119)		(0.137)	(0.156)
Public clients	0.243*	-0.044		0.296	0.121
	(0.146)	(0.200)		(0.192)	(0.380)
Competitors	0.152	0.142		-0.045	
	(0.145)	(0.168)		(0.176)	
Consultants, private R&D	0.002	-0.002		-0.142	0.135
	(0.103)	(0.128)		(0.164)	(0.134)
Universities, HEI	-0.026	0.030		0.091	0.025
	(0.097)	(0.123)		(0.127)	(0.153)
Government	-0.160	-0.111		-0.128	-0.452*
	(0.128)	(0.166)		(0.179)	(0.260)
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	No	No	Yes	Yes
N	498	281	186	344	139
Pseudo R2	0.177	0.217	0.228	0.188	0.298
Chi2	120.4	79.98	53.43	88.79	62.94

Source: Authors' estimates based on data from the CSO.

Notes: The figures reported in the table are marginal effects. Robust standard errors are reported in parentheses. *, **, *** denote significance at 10%, 5% and 1% respectively.

6 Conclusions

This paper examines determinants of the propensity of firms to introduce innovations with environmental benefits. Using micro data from Ireland, we examine a range of factors suggested by previous international evidence including: environmental regulations, innovation inputs, firm-specific characteristics, spillovers from other firms with green innovations (in the same industry and in the same region), co-operation for innovation activities, and public funding. The analysis considers all innovations with environmental benefits as well as two specific innovation categories, namely innovations with within firm environmental benefits and innovations with environmental benefits for the final consumer. Further, within these two broad innovation categories, we analyse green innovations by type of environmental impact. In addition to average effects across all firms, to account for potentially different innovation behaviours for different groups of firms, we analyse separately manufacturing and services firms and indigenous and foreign-owned firms.

The key results indicate that environmental regulations, in-house R&D and acquisition of capital assets are major drivers of green innovations. Larger firms are more likely to introduce green innovations. This result holds for all firms as well as all subsamples of firms with the exception of firms in services. The propensity of services firms to introduce green innovations is higher for firms in the same industry with green innovators. Such a spillover effect is not identified in the case of the other groups of firms. Relative to foreign-owned firms, indigenous firms are more likely to introduce green innovations with benefits for the end user. This result holds across all firms as well as for manufacturing and services firms.

Our results indicate that firms engaged in co-operation for innovation with firms in the same enterprise group and with competitors are more likely to introduce green innovations. The effect of co-operations with firms in the same enterprise group is driven by foreign-owned firms while the positive effect of co-operations with competitors is driven by firms in services and indigenous firms. Co-operation with private clients increases the propensity of firms to introduce green innovations.

Public funding appears to play a limited role on fostering the introduction of green innovations. Our results indicate a positive albeit marginally significant effect in the case of funding from local authorities on the propensity of firms to introduce green innovations. This effect appears to be driven by firms in services while it does not appear to be statistically significant in the case of the other groups of firms. Public funding from the European Union is found to be positively and significantly associated with green innovations with benefits for the end user in the area of more durable products. This effect is identified for manufacturing firms and for indigenous firms. It is not statistically significant in the case of firms in services and foreign-owned firms.

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Appendix

Table A1: Definitions of Variables and Data Sources

Dependent Variables

Variable	Definition	Data Sources
Innovation with environmental benefits	1 if firm implemented any innovation with environmental benefits between 2012 and 2014	CIS 2014
Innovation with environmental benefits within the enterprise	1 if firm implemented any innovation with environmental benefits within the enterprise between 2012 and 2014	CIS 2014
Innovation with environmental benefits for the end user	1 if firm implemented any innovation with environmental benefits for the end user between 2012 and 2014	CIS 2014
Innovation with enterprise benefits: reduced material or water use	Innovation with environmental benefits within the enterprise 2012-2014: reduced material or water use per unit of output	CIS 2014
Innovation with enterprise benefits: reduced energy use or CO2 footprint	Innovation with environmental benefits within the enterprise 2012-2014: reduced energy use or CO2 footprint	CIS 2014
Innovation with enterprise benefits: reduced air, water, noise or soil pollution	Innovation with environmental benefits within the enterprise 2012-2014: reduced air, water, noise or soil pollution	CIS 2014
Innovation with enterprise benefits: Less polluting or hazardous substitutes	Innovation with environmental benefits within the enterprise 2012-2014: replaced a share of materials with less polluting or hazardous substitutes	CIS 2014
Innovation with enterprise benefits: Renewable energy sources	Innovation with environmental benefits within the enterprise 2012-2014: replaced a share of fossil energy with renewable energy sources	CIS 2014
Innovation with enterprise benefits: Recycled waste, water or materials	Innovation with environmental benefits within the enterprise 2012-2014: recycled waste, water, or materials for own use or sale	CIS 2014
Innovation with benefits for the end user: Reduced energy use or CO2 footprint	Innovation with environmental benefits for the end user 2012-2014: reduced energy use or CO2 footprint	CIS 2014
Innovation with benefits for the end user: Reduced air, water, noise or soil pollution	Innovation with environmental benefits for the end user 2012-2014: reduced air, water, noise or soil pollution	CIS 2014
Innovation with benefits for the end user: Facilitated recycling after use	Innovation with environmental benefits for the end user 2012-2014: facilitated recycling of product after use	CIS 2014

Innovation with benefits for the end user: More durable products	Innovation with environmental benefits for the end user 2012-2014: extended product life through longer-lasting, more durable products	CIS 2014
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Explanatory Variables

Variable	Definition	Data Source
Environmental Regulations		
Pre-2012	1 if firm implemented procedures to regularly identify and reduce environmental impacts before 2012	CIS 2014
Post-2012	1 if firm implemented or significantly changed procedures to regularly identify and reduce environmental impacts between 2012 and 2014	CIS 2014
Innovation inputs		
In-house R&D	1 if firm had in-house R&D	CIS 2014
External R&D	1 if firm had external R&D	CIS 2014
Machinery, equipment, software & buildings	1 if firm acquired machinery, equipment, software or buildings	CIS 2014
Other external knowledge	1 if firm made use of other external knowledge from other enterprises or institutions	CIS 2014
Other innovation activities	1 if firm implemented any other innovation activity	CIS 2014
Firm-specific factors		
Productivity 2012	Log of turnover/employment in 2012	CIS 2014
Size (employment quartile)	Firm size by number of employees (employment quartile)	CIS 2014
Exported to Europe	1 if firm exported to Northern Ireland, other EU countries, EFTA or EU candidates	CIS 2014
Exported to other destinations	1 if firm exported to other countries	CIS 2014
Environmental spillover (industry level)	Spillover from other environmental innovations in the same industry	CIS 2014
Environmental spillover (innovations with benefits within the enterprise, industry level)	Spillover from other environmental innovations in the same industry (with benefits within the enterprise)	CIS 2014
Environmental spillover (innovations with benefits for the end user, industry level)	Spillover from other environmental innovations in the same industry (with benefits for the end user)	CIS 2014

Wage per employee	Wage per employee in 2011 (thousand euros)	CIP and ASI 2011
Export sales ratio	Exports to sales ratio in 2011	CIP and ASI 2011
Import sales ratio	Imports to sales ratio in 2011	CIP and ASI 2011
Fuel sales ratio	Fuel consumption to sales ratio in 2011	CIP and ASI 2011
Firm market share	Firm market share in industry in 2011	CIP and ASI 2011
Public financial support		
Local/Regional authorities	1 if innovation funded by local or regional authorities	CIS 2014
Central government	1 if innovation funded by central government	CIS 2014
European Union	1 if innovation funded by the European Union	CIS 2014
Type of ownership		
Indigenous firm	1 if domestic-owned firm is domestic-owned	CIS 2014
USA ownership	1 if foreign-owned by US based multinational	CIS 2014
EU ownership	1 if foreign owned by EU based multinational	CIS 2014
Type of co-operation partner		
Enterprise group	Other enterprises in firms' enterprise group	CIS 2014
Suppliers	Suppliers of equipment, materials, components or software	CIS 2014
Private clients	Clients or costumers from the private sector	CIS 2014
Public clients	Clients or costumers from the public sector	CIS 2014
Competitors	Competitors or other enterprises in firm i's sector	CIS 2014
Consultants, private R&D	Consultants, commercial labs or private R&D institutes	CIS 2014
Universities, HEI	Universities or other higher education institutions	CIS 2014
Government	Government or public or private research institutions	CIS 2014
Persistence		
Previous green innovator	1 if firm implemented any innovation with environmental benefits between 2006 and 2008 (persistence variable for every type of green innovation)	CIS 2008