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***Keywords:** Environmental policy, green innovations, export performance.*

***JEL Classification**: F14, O33, Q56*

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Green Innovations and Export Performance[1]

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Abstract

This paper examines the relationship between innovations with environmental benefits (green innovations) and firms' export performance. Using firm-level data from Ireland's Community Innovation Survey over 2012-2014, we examine whether and to what extent green innovations are associated with firms' export participation and with the intensity of their exports. Our estimates indicate that innovations with environmental benefits for the consumer and product innovations with environmental benefits were positively associated with firms' export participation. Further, our results indicate that green innovations do not appear to impact on how much firms export. Taken together, our results suggest that environmental policy-induced innovations could be beneficial for the international competitiveness of firms measured as export participation.

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1 Introduction

This paper provides novel evidence on the relationship between innovations with environmental benefits (green innovations) and firms' export performance. While the relationship between environmental policy and firms' competitiveness has been discussed extensively over the past two decades, there is very little evidence on whether and to what extent innovations with environmental benefits affect firms' export participation and the extent of their export sales. This new evidence could help to improve the understanding of economic effects of environmental policies and the design of environmental and enterprise policies aimed at fostering a more sustainable long-term economic growth.

The early conventional view of economists on the environmental policy-competitiveness nexus was that while regulations improve environmental quality, they constrain the optimal allocation of resources, increase firms' costs and slow down productivity growth with negative effects on their competitiveness (Gray 1987; Barbera and McConnell 1990; Gollop and Roberts 1983; Smith and Sims 1985). In contrast to this conventional view, Porter (1991) and Porter and van der Linde (1995) have put forward the hypothesis that well-designed environmental regulations can improve the environmental performance of firms and foster their international competitiveness by inducing technological innovations. To be successful, such policies should take into account multiple objectives beyond profit maximization and short run efficiency. The Porter Hypothesis has generated a rich theoretical and empirical literature.

Theoretical models based on endogenous technology responses to environmental policy provide support to the Porter Hypothesis (Bovenberg and Smulders 1995, 1996; Aghion et al. 1997; Aghion and Howitt 1998; Goulder and Schneider 1999; Ambec and Barla 2002; Ambec and Lanoie 2008; van der Zwaan et al. 2002; Popp 2004; André et al. 2009). In an important contribution to modelling the technology response to environmental policy, Acemoglu et al. (2012) go beyond these studies and develop a comprehensive theoretical framework with endogenous and directed technological change introduced in a growth model with environmental constraints. Under the assumption that inputs from the "dirty" and "clean" sectors are highly substitutable, their model shows that temporary policy interventions, such as carbon taxes or research subsidies, would be sufficient to redirect innovation towards clean inputs. To avoid an excessive use of carbon taxes, the optimal policy mix would include both carbon taxes and research subsidies. The authors point out that, in contrast to implications from models with exogenous technology used in previous analyses (Nordhaus 1994, 2007, 2009; Nordhaus and Boyer 2000; Weitzman 2009; Golosov et al. 2011), early and decisive

intervention is key to the rapid reallocation of R&D resources to clean technologies. Delayed intervention will be costly as it would lead to a longer transition period with slow growth. These results imply that environmental goals can be achieved with targeted temporary government intervention and without jeopardizing long-term economic growth.

The empirical evidence so far indicates that environmental policy does not have significant adverse effects on firms' competitiveness. An early contribution by Jaffe et al. (1995) finds no strong evidence of adverse effects of environmental regulations on firms' competitiveness. Overall, they find that the effects of environmental regulations on net exports, trade flows, and plant-location decisions were either small, statistically insignificant, or not robust to tests of model specification. Recent reviews of the international evidence confirm these empirical findings (Dechezleprêtre and Sato 2017; Dechezleprêtre et al. 2019). A number of studies find no strong evidence on negative effects of Environmental Tax Reform (ETR) and climate actions on employment, income distribution, economic growth and export performance (Barker et al. 2007). Costantini and Mazzanti (2012) find no overall adverse effects of environmental policies (environmental and energy tax policies) on the competitiveness of the manufacturing sector in EU15. Their results indicate that the benefits from export competitiveness are greater when the regulatory framework is followed by innovation. The positive effects of environmental policies on export competitiveness are stronger in higher technology sectors.

There is strong evidence on innovation induced by environmental regulations (a recent review of international evidence is provided by Siedschlag et al. 2019). Aghion et al (2016) find that firms tend to innovate more in cleaner technologies in response to higher road fuel prices. Calel and Dechezleprêtre (2016) provide evidence showing that the EU ETS has increased innovation activity in low-carbon technologies among regulated companies by 30 percent relative to a control group.

While there is strong evidence that environmental regulations induce innovation activity in cleaner technologies there is a lack of evidence that the benefits from these innovations lead to an increase in firms' competitiveness (Dechezleprêtre and Sato 2017). In contrast, there is evidence suggesting that environmental policy can increase firms' productivity via knowledge spillovers on innovation and the adoption of cleaner technologies (Greaker 2006; Mohr 2002). Further recent evidence finds that regulation-induced innovation in clean technologies increase the innovation activity and competitiveness of unregulated companies through knowledge spillovers (Dechezleprêtre, Martin and Mohnen 2014). Further evidence indicates that policy-induced innovation lowers the cost of achieving environmental quality (Harrington,

Morgenstern and Nelson 2000; Simpson 2014) and that policy-induced innovation and environmental strategies co-evolve (Wagner 2007). Additional relevant evidence indicates that properly designed regulations can boost demand for green products (Wagner 2006) and that regulations improve productivity in sectors exposed to international competition (Lanoie et al. 2008).

Against this background, using firm-level data from Ireland, we contribute to filling the evidence gap in the literature on the relationship between policy-induced green innovations and firms' competitiveness measured as export performance. Specifically, using firm-level data from Ireland's Community Innovation Survey over 2012-2014, we examine whether and to what extent green innovations are associated with firms' export participation and with the intensity of their exports. Our estimates indicate that green innovations with benefits for the consumer and product innovations with environmental benefits were positively associated with export participation. The propensity to export is higher by 7.2 percentage points in the case of firms with innovations with environmental benefits for the consumer and by 10.2 percentage points in the case of firms with product innovations with environmental benefits. Further, we find that exports are quite persistent, with firms having exported in 2012 highly likely to also export in 2014. Finally, our results indicate that conditional on export participation, green innovations do not appear to impact on how much firms export. Taken together, our results suggest that environmental policy-induced innovations could be beneficial for the international competitiveness of firms measured as export participation.

The remainder of this paper is organized as follows. Section 2 discusses the analytical framework and the econometric methodology for the analysis. Next, section 3 describes the data and summary statistics of the variables. Section 4 discusses the empirical estimates and section 5 concludes.

2 Analytical Framework and Econometric Methodology

The theoretical background for our empirical analysis is the Porter Hypothesis discussed in the Introduction. Following on from the Porter mechanism as formalized by Ambec and Lanoie (2008), environmental regulations induce green innovations which can increase competitiveness and exports via demand for new products and better access to new markets. While the impact of green innovations on export performance has been less investigated, the literature on innovation and exporting offers useful insights for an analytical framework.

Product-cycle models of international trade predict that exports in industrialised countries are driven by innovation (Vernon, 1966; Krugman, 1979). There is a small but growing literature on the relationship between innovation and exporting at the firm level. In the case of the United Kingdom, Wakelin (1998) finds a positive and statistically significant correlation between innovation and exporting, and Bleaney and Wakelin (2002) find that firms in R&D intensive (innovative) sectors are more likely to export. In the case of Spanish manufacturing firms, Cassiman et al. (2010) find that while product innovation drives firms' propensity to export, process innovation does not. In contrast, using the same data set, Caldera (2010) finds that both product and process innovation are associated with exporting. These results are robust to accounting for endogeneity and other robustness checks. Cassiman and Golovko (2011) provide further evidence from Spain on product innovation as a driver of export participation. Becker and Egger (2013) find that German firms which introduced both product and process innovation experienced a higher propensity to export. On the other hand, Damijan et al. (2010) using firm level data from Slovenia and Van Beveren and Vandenbussche (2010) using data for Belgian firms find no significant effect of either product or process innovation on export propensity.

While most studies have examined the relationship between innovation and the extensive margin of exporting, innovation could also impact on how much firms export, the intensive margin of exporting. The evidence on the link between innovation and export intensity is mixed. Pla-Barber and Alegre (2007) find a positive and significant effect of innovation on the export intensity of firms in the French biotechnology industry. Elliot et al. (2019) find a positive impact of innovation on exports through the intensive margin in the case of French manufacturing firms. In contrast, they find that innovation does not affect the extensive margin of exports. In contrast, in the case of new technology-based UK firms, Ganotakis and Love (2010) find that while product innovators are more likely to export, conditional on entering export markets, product innovation does not affect the intensity of exports. Tavassoli (2018)

provides evidence from Sweden on the positive effects of product and process innovations on the propensity of firms to export as well as well as on the intensity of exports.

To the best of our knowledge, there is no analysis so far on the links between innovations with environmental benefits and export performance. Our analysis combines insights from environmental economics on the Porter Hypothesis and the literature on international trade and innovation. Given that we only observe the export sales reported by exporters, we model firms' export performance as a two-step model: in the first stage (export selection equation) we estimate export participation as a function of innovations with environmental benefits and other factors which have been found to influence the propensity of firms to export including firm size, R&D activity, productivity, previous exporting activity and ownership, as well as unobserved industry characteristics.

The export selection equation to be estimated is as follows:

$$y_i = \begin{cases} 1 \; if \; y_i^* = x_i\gamma + \mu_i > \tau \\ 0 \; if \; y_i^* = x_i\gamma + \mu_i \leq \tau \end{cases} \quad (1)$$

y_i is an observed binary variable which equals one for firms reporting export sales, and 0 for the rest of the firms. Firms engage in exports or report export sales if y_i^*, an unobserved latent endogenous variable measuring firms' propensity to export is above a certain level, τ. This latent variable can be interpreted as a decision criterion, such as the expected profit value of a firm's profit due to exporting. x_i is the vector of variables explaining the decision of firms to engage in exporting, γ, is the vector of the related parameters, and μ_i is the error term.

In the second stage, (export intensity equation), we estimate export intensity conditional on export participation, as a function of innovations with environmental benefits and other factors including the intensity of R&D expenditures, productivity, previous exporting experience, and unobserved industry characteristics. For identification purposes, the excluded variable in the intensity equation is firm size assuming that among exporters, export sales increase monotonically with firm size and export intensity measured as export sales over total sales is independent of firm size. The intensity of exports for a given firm *i* measured as the share of export sales in total sales v_i is given by the following equation:

$$v_i = \begin{cases} v_i^* = z_i\beta + \omega_i \; if \; y_i = 1 \\ 0 \qquad if \; y_i = 0 \end{cases} \quad (2)$$

v_i^* is the unobserved latent export intensity variable, z_i is a vector of variables explaining export intensity and ω_i is the error term.

Assuming that the error terms in Eq (1) and (2) are correlated and that they follow a bivariate normal distribution with zero mean, we estimate the two equations simultaneously using the Heckman two-step estimator following Heckman (1976, 1979).

3 Data and Summary Statistics

The data used for this analysis comes from the Community Innovation Survey (CIS) 2014 which provides information on innovation activities of enterprises with 10 and more employees from industry and market-based services in Ireland over the period 2012-2014. It is a stratified random sample, stratified by firm size and 2-digit industries at national level. The data set we analyse contains anonymized information on 3036 firms.

The CIS 2014 survey carried out by the Central Statistics Office (CSO) includes questions on whether firms introduced innovations with environmental benefits (green innovations) during the survey period. Questions regarding firms' introduction of green innovations were included only in the 2008 and 2014 CIS waves. The dataset used for this analysis covers the period 2012-2014. Given that not all firms are surveyed every time, linking the CIS 2014 with the CIS 2008 data resulted in a substantially reduced number of observations compared to the cross-section data from the CIS 2014. The choice of using the CIS 2014 data set is motivated by the objective to maximize the number of observations and the representativeness of the analyzed sample. The trade-off is in terms of not being able to control for unobserved factors that may influence the innovation and export performance of firms. Our results should therefore be interpreted as structural links rather than causal relationships.

Table 1 shows summary statistics of the variables used in the analysis of the relationship between green innovations and export performance. Detailed definitions of the variables used in the analysis are given in Table A1 in the Appendix. On average, 40% of all enterprises report green innovations over 2012-2014. Taking into account the beneficiary of the green innovations, on average across all firms, the innovation rate is highest for green innovations with benefits for the enterprise, 34%, while 28% of enterprises have introduced green innovations with benefits for the consumer. The higher innovation rate for innovations with environmental benefits for the enterprise is likely to be induced by environmental regulations, as shown by Siedschlag, Meneto, and Tong Koecklin (2019). Across green innovations types,

the innovation rate is the highest for organizational innovation, 27%, followed by process innovation, 24%, marketing innovation, 23%, and product innovation, 22%.

Table 1: Summary statistics, all firms, 2012-2014

Variables	(1) Obs.	(2) Mean	(3) St. Dev.	(4) Min	(5) Max
Green Innovation	3036	0.401	0.490	0	1
Green Innovation with Benefits for the Enterprise	3036	0.340	0.474	0	1
Green Innovation with Benefits for the Consumer	3036	0.280	0.449	0	1
Green Product Innovation	3036	0.224	0.417	0	1
Green Process Innovation	3036	0.241	0.428	0	1
Green Organizational Innovation	3036	0.269	0.443	0	1
Green Marketing Innovation	3036	0.231	0.422	0	1
Export intensity in 2014	3036	0.268	0.376	0	1
Exporter in 2012	3036	0.547	0.498	0	1
Exporter in 2014	3036	0.563	0.496	0	1
R&D Intensity in 2012 (in logs)	2794	-7.677	4.136	-18.601	8.854
Foreign Ownership	3036	0.147	0.354	0	1
Employment in 2012 (in logs)	2842	3.570	1.282	0.000	12.525
Productivity in 2012 (in logs)	2767	6.160	3.198	-7.233	16.550

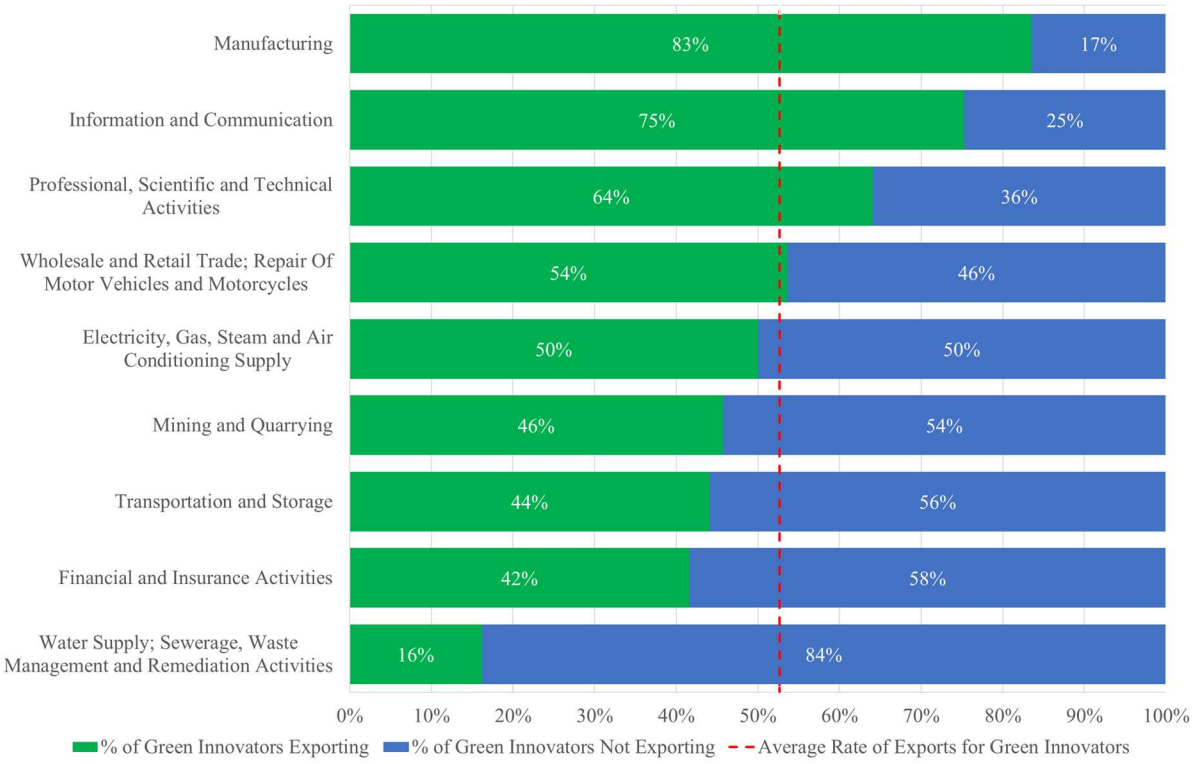
Source: Authors' calculations based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure 1 shows the proportion of exporting and non-exporting firms by sector for green innovators over the analysed period. The three top sectors with the highest export participation rates are Manufacturing; Information and Communication; and Professional, Scientific and Technical Activities. The three lowest export participation rates are in Transportation and Storage; Financial and Insurance Activities; Water Supply, Sewerage, Waste Management and Remediation Activities.

Figures 2 and 3 below report export participation rates for firms that introduced innovations with environmental benefits for the enterprise and for the consumer, respectively. For both

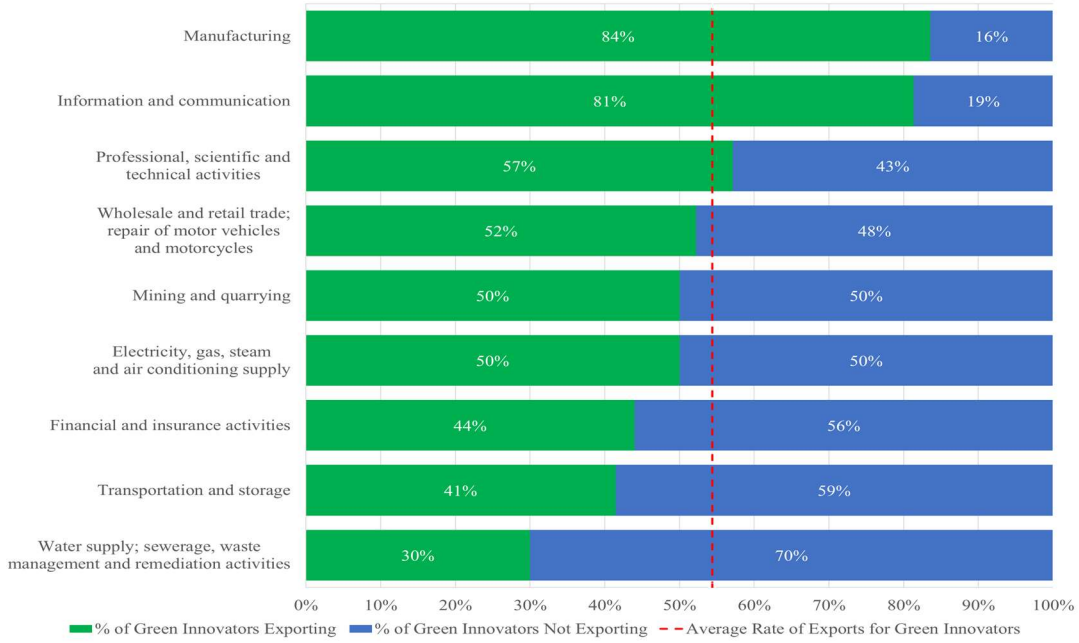
green innovators groups, firms within the top three sectors reporting exports as well as introducing green innovations are in Manufacturing; Information and Communication; and Professional, Scientific and Technical Activities. At the other end of the spectrum, the lowest export participation rates are in Water Supply, Sewerage, Waste Management and Remediation Activities; Financial and Insurance Activities; and Transportation and Storage sectors.

Figure 1: Export participation of green innovators by sector



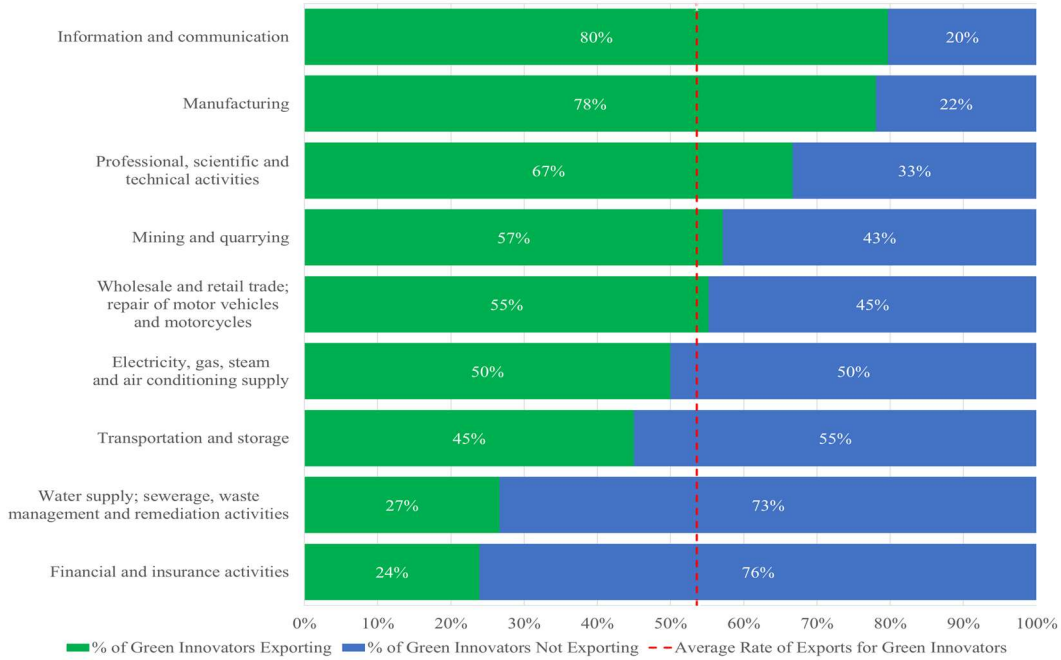
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure 2. Export participation of green innovators by sector – innovations with environmental benefits for the enterprise



Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure 3. Export participation of green innovators by sector – innovations with environmental benefits for the consumer



Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

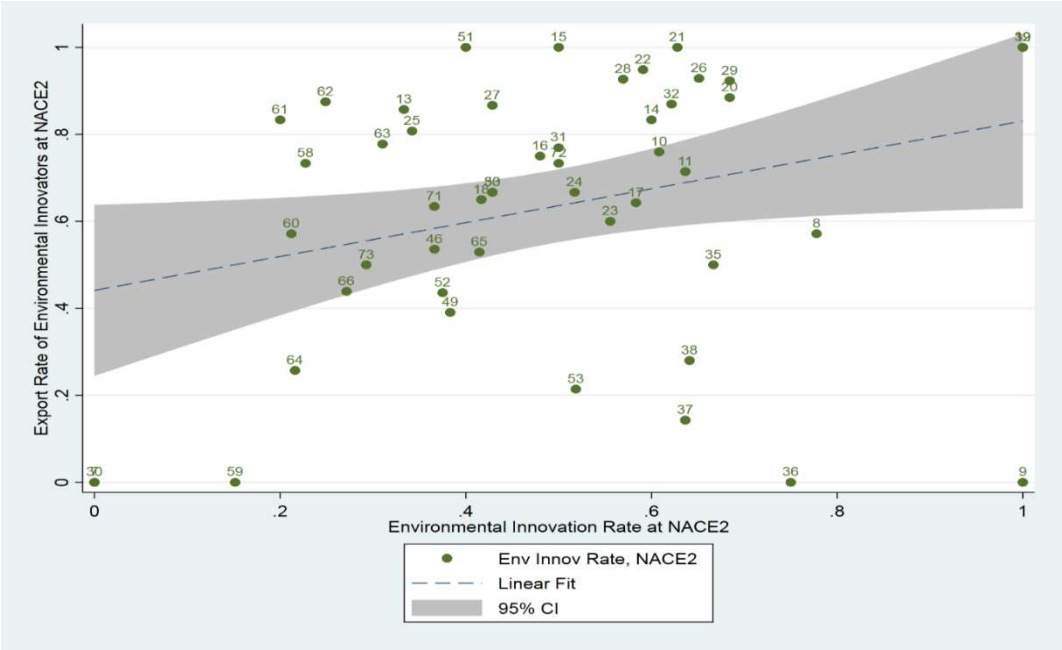
Figures A1-A4 in the Appendix show export participation rates by types of green innovations. The sectoral patterns of export participation vary across the four types of innovations with environmental benefits. Among firms that introduced product innovations with environmental benefits (Figure A1), the top three export participation rates are in the sectors: Information and Communication; Manufacturing; and Mining and Quarrying. The bottom three export participation rates are in the sectors: Water Supply, Sewerage, Waste Management and Remediation Activities; Financial and Insurance Activities; and Transportation and Storage.

The composition of the top and bottom three sectors with respect to export participation rates among firms that introduced process innovations with environmental benefits (Figure A2), varies only in that the top three sectors include: Electricity, Gas, Steam and Air Conditioning Supply in place of Information and Communication, along with Manufacturing, and Mining and Quarrying.

The top and bottom sectors with respect to export participation rates of firms with organizational and marketing innovations with environmental benefits are different from the previous two green innovation types. With respect to firms that introduced organizational innovations with environmental benefits (Figure A3), the top three export participation rates are in the sectors: Manufacturing; Information and Communication; and Wholesale and Retail Trade, Repair of Motor Vehicles and Motorcycles. The bottom three export participation rates are in the sectors: Electricity, Gas, Steam and Air Conditioning Supply; Transportation and Storage; and Financial and Insurance Activities. Finally, the top three export participation rates of firms that introduced marketing innovations with environmental benefits (Figure A4) are in the sectors: Professional, Scientific and Technical Activities; Information and Communication; and Manufacturing. The bottom three export participation rates are in the sectors: Mining and Quarrying; Financial and Insurance Activities; and Transportation and Storage.

Figure 4 shows that green innovation rates by industry are positively correlated with industry-specific export participation rates. Figures A5 to A10 plot the green innovation rates by industry against the export participation rate by industry for each individual type of green innovation. While all figures display a positive relationship between the two variables, the strength of the correlation varies across the types of green innovations. The correlation between innovation and export participation rates appear to be strongest in the cases of product and process innovations with environmental benefits.

Figure 4. Correlation of green innovation rates and export participation rates by industry, all green innovations, 2012-2014



Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Table 3 shows the estimated correlations between green innovation and export intensity controlling for firm size and unobserved industry characteristics. The results indicate significant innovation premia for all types of green innovations with the exception of marketing innovations with environmental benefits. When all green innovations are considered, relative to firms with no green innovations, on average the export intensity of green innovators is higher by 3.3%. Considering the beneficiary of green innovations, the green innovation premium is higher for green innovations with benefits for the enterprises 2.9%, while the corresponding premium for green innovations with benefits for the consumer is 2.6%. Across the different types of innovations, the green innovation premium at 7.6% is the largest for product innovations with environmental benefits, followed by a premium of 5.8% for process innovations with environmental benefits, and a premium of 3.4% for organizational innovations with environmental benefits.

Table 3: Green Innovation *Premia* by Innovation Type

Dep. Var.: Export intensity in 2014 (in log)							
All Green Innovations	0.0329**						
	(0.0132)						
Green Innov. with Benefit for Enterprise		0.0292**					
		(0.0137)					
Green Innov. With Benefit for Consumer			0.0262*				
			(0.0139)				
Green Product Innovations				0.0762***			
				(0.0164)			
Green Process Innovations					0.0575***		
					(0.0155)		
Green Marketing Innovations						0.0148	
						(0.0149)	
Green Organizational Innovations							0.0341**
							(0.0145)
Employment in 2012	0.0578***	0.0579***	0.0589***	0.0548***	0.0563***	0.0594***	0.0578***
	(0.0058)	(0.0058)	(0.0057)	(0.0058)	(0.0057)	(0.0057)	(0.0058)
Constant	-0.0594***	-0.0599***	-0.0637***	-0.0477**	-0.0533**	-0.0657***	-0.0593***
	(0.0229)	(0.0230)	(0.0227)	(0.0228)	(0.0228)	(0.0228)	(0.0229)
Industry NACE 2-digit Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,842	2,842	2,842	2,842	2,842	2,842	2,842
R-squared	0.282	0.281	0.281	0.287	0.284	0.281	0.282

Source: Authors' estimates based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Notes: Robust standard errors in parentheses. ***, **, * denote statistical significance at 1%, 5%, and 10%, respectively.

4 Empirical Results

Table 4 shows the estimates obtained with the two-step Heckman model described in Section 2 on the links between firms' green innovations and their export performance. The results of the first stage model indicate that over and above other factors, firms with green innovations are more likely to export relative to the rest of firms. However, this positive association is statistically significant only in the case of innovations with environmental benefits for the consumer and in the case of product innovations with environmental benefits. The green innovators' propensity to export is higher by 7.2 percentage points in the case of firms with innovations with environmental benefits for the consumer and by 10.2 percentage points in the case of firms with product innovations with environmental benefits. The results from the first stage also indicate that firms that exported in 2012 were highly likely to also export in 2014.

The results of the second stage of the model indicate that, conditional on exporting, green innovations do not have a significant effect on the intensity of firms' exports over and above other factors. Such factors which influence how much firms export include productivity, R&D intensity and foreign ownership. Firms' export intensity is associated with higher productivity and with higher R&D intensity. When all green innovations are considered, on average, an increase by ten per cent in productivity is associated with export intensity higher by 0.8 per cent. On average, a higher R&D intensity by ten per cent is associated with export intensity higher 0.9 per cent. The export intensity gains associated with a ten per cent increase in productivity across the different types of green innovations range from 0.84 per cent (in the case of process innovations with environmental benefits) to 0.87 per cent (in the case of marketing innovations with environmental benefits). Further, the export gains associated with a ten per cent increase in R&D intensity range from 0.88 per cent (in the case of process innovations with environmental benefits) to 0.92 per cent (in the case of marketing innovations with environmental benefits). Conditional on exporting, foreign-owned firms have a higher export intensity relative to local firms. The foreign ownership premium in terms of export intensity is 63.5% in the case of all green innovations and it ranges across the different green innovation types from 63.7% (in the case of innovations with environmental benefits for the enterprise) to 64.0% (in the cases of innovations with environmental benefits for the consumer and product innovations with environmental benefits).

Table 4: The relationship between green innovations and export performance

First stage: Dep. Var.: Export Participation in 2014							
All Green Innovations	0.0399						
	(0.0318)						
Green Innovation - Benefit for Consumer		**0.0715****					
		(0.0306)					
Green Innovation - Benefit for Enterprise			0.0265				
			(0.0336)				
Green Product Innovations				**0.1020*****			
				(0.0350)			
Green Process Innovations					0.0306		
					(0.0383)		
Green Organizational Innovations						0.0470	
						(0.0357)	
Green Marketing Innovations							0.0417
							(0.0362)
R&D Activity (Dummy)	0.0875*	0.0855*	0.0903**	0.0626	0.0863*	0.0830*	0.0850*
	(0.0448)	(0.0455)	(0.0443)	(0.0482)	(0.0457)	(0.0456)	(0.0451)
Productivity in 2012	-0.0074*	-0.0076*	-0.0074*	-0.0067	-0.0074*	-0.0073*	-0.0072*
	(0.0044)	(0.0044)	(0.0044)	(0.0043)	(0.0047)	(0.0047)	(0.0044)
Exporter in 2012	1.146***	1.148***	1.146***	1.141***	1.146***	1.146***	1.147***
	(0.0370)	(0.0373)	(0.0369)	(0.0373)	(0.0369)	(0.0370)	(0.0369)
Foreign Ownership	0.0147	0.0183	0.0145	0.0146	0.0150	0.0150	0.0171
	(0.0450)	(0.0445)	(0.0451)	(0.0445)	(0.0451)	(0.0452)	(0.0452)
Employment in 2012	-0.0170	-0.0183*	-0.0164	-0.0201*	-0.0165	-0.0177	-0.0170
	(0.0112)	(0.0109)	(0.0112)	(0.0110)	(0.0112)	(0.0111)	(0.0111)
Industry NACE 1-digit Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Second stage: Dep. Var.: Export intensity in 2014 (in log)							
All Green Innovation	0.0571						
	(0.0651)						
Green Innovation - Benefit for Consumer		0.0479					
		(0.0688)					
Green Innovation - Benefit for Enterprise			0.0339				
			(0.0664)				
Green Product Innovations				0.0276			
				(0.0741)			
Green Process Innovations					0.0648		
					(0.0714)		
Green Organizational Innovations						0.0105	
						(0.0687)	
Green Marketing Innovations							-0.0270
							(0.0712)
Productivity in 2012	0.0848***	0.0851***	0.0857***	0.0850***	0.0839***	0.0859***	0.0870***
	(0.0176)	(0.0176)	(0.0176)	(0.0178)	(0.0178)	(0.0177)	(0.0177)
Exporter in 2012	0.740	1.390	0.453	1.169	0.551	0.657	0.505
	(1.158)	(1.169)	(1.137)	(1.117)	(1.168)	(1.167)	(1.162)
R&D Intensity in 2012	0.0894***	0.0918***	0.0898***	0.0909***	0.0879***	0.0907***	0.0917***
	(0.0133)	(0.0132)	(0.0133)	(0.0137)	(0.0136)	(0.0134)	(0.0134)
Foreign Ownership	0.635***	0.640***	0.637***	0.640***	0.637***	0.639***	0.639***
	(0.0817)	(0.0813)	(0.0819)	(0.0813)	(0.0817)	(0.0817)	(0.0817)
Constant	-2.610	-3.234*	-2.295	-3.012*	-2.393	-2.499	-2.347
	(1.696)	(1.704)	(1.684)	(1.669)	(1.704)	(1.703)	(1.701)
Industry NACE 2-digit Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lambda	-0.294	0.0713	-0.458	-0.0531	-0.399	-0.344	-0.430
Wald chi2 Second Stage	501.94	504.53	498.99	501.82	500.65	500.1	499.73
Wald chi2 First Stage	1426.68	1435.4	1427.37	1410.3	1426.71	1422.06	1425.2

Pseudo R^2 First Stage	0.7622	0.763	0.7619	0.7637	0.7619	0.7622	0.7621
Observations	2,767	2,767	2,767	2,767	2,767	2,767	2,767

Source: Authors' estimates based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Notes: Estimates are marginal effects obtained with a Heckman two-step model. Standard errors are shown in parentheses. ***, **, * denote statistical significance at 1%, 5%, and 10%.

6 Conclusions

This paper examines the relationship between firms' green innovations and their international competitiveness. The analytical framework combines insights from environmental economics on the Porter Hypothesis and the literature on international trade and innovation. Using firm-level data from Ireland's Community Innovation Survey over 2012-2014, we examine whether and to what extent green innovations are associated with firms' export participation and with the intensity of their exports. We consider all green innovations as well as different groups of innovations with environmental benefits by the beneficiary of innovations (innovations with environmental benefits for the enterprise; innovations with innovation benefits for the consumer) and by innovation outcomes (product, process, organizational and marketing innovations).

On average, 40% of all enterprises report green innovations over 2012-2014. Taking into account the beneficiary of the green innovations, on average across all firms, the innovation rate is the highest at 34% for green innovations with benefits for the enterprise, while 28% of enterprises have introduced green innovations with benefits for the consumer. Across green innovations types, the innovation rate at 27% is the highest for organizational innovation, followed by process innovation at 24%, marketing innovation at 23%, and product innovation, at 22%.

Our results indicate that green innovations with benefits for the consumer and product innovations with environmental benefits are positively associated with export participation. The propensity to export is 7.2 percentage points higher in the case of firms with innovations with environmental benefits for the consumer and by 10.2 percentage points in the case of firms with product innovations with environmental benefits. The results from the first stage also indicate that export participation is quite persistent, with firms having exported in 2012 highly likely to also export in 2014. Further, our results indicate that conditional on firms' export participation, green innovations do not appear to impact on how much firms export.

Taken together, our results suggest that environmental policy-induced innovations could be beneficial for the international competitiveness of firms measured by their export participation.

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Appendix

Table A1: Definitions of Variables and Data Sources

Variables	Definitions	Data Sources
Dependent Variables		
Export Participation in 2014	1 if firm exported in 2014	CIS 2014
Export Intensity 2014	Export sales/turnover in 2014	CIS 2014
Explanatory Variables **Green Innovations**		
Green Innovation	1 if firm implemented any innovation with environmental benefits between 2012 and 2014	CIS 2014
Green Innovation - Benefit for Enterprise	1 if firm implemented any innovation with environmental benefits within the enterprise between 2012 and 2014	CIS 2014
Green Innovation - Benefit for Consumer	1 if firm implemented any innovation with environmental benefits for the end user between 2012 and 2014	CIS 2014
Green Product Innovation	1 if firm implemented any product innovation with environmental benefits between 2012 and 2014	CIS 2014
Green Process Innovation	1 if firm implemented any process innovation with environmental benefits between 2012 and 2014	CIS 2014
Green Organizational Innovation	1 if firm implemented any organizational innovation with environmental benefits between 2012 and 2014	CIS 2014
Green Marketing Innovation	1 if firm implemented any marketing innovation with environmental benefits between 2012 and 2014	CIS 2014
Firm-Specific Characteristics		
Productivity 2012	Turnover/employment in 2012	CIS 2014
Employment in 2012	The average number of employees in 2012	CIS 2014
R&D Intensity, in 2012	Total R&D expenditures (In-House and External R&D)/turnover in 2012	CIS 2014
Exporter in 2012	1 if firm exported in 2012	CIS 2014
Ownership	1 if firm is foreign-owned	CIS 2014

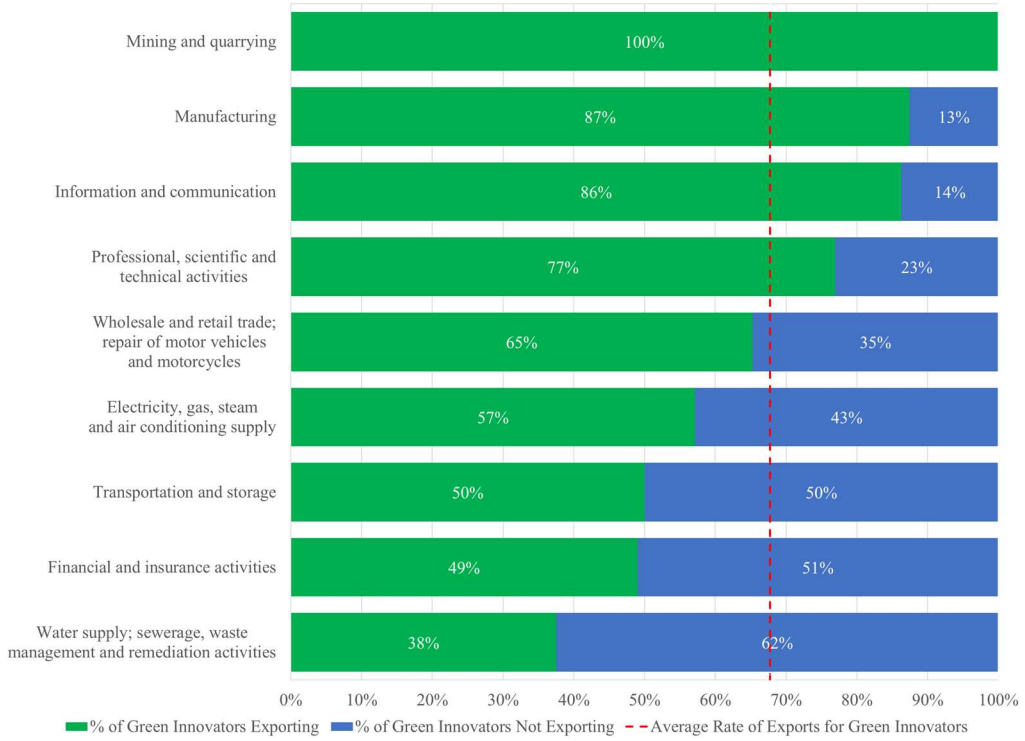
Table A2: NACE Rev.2 Industry classification

Sector	Industry Code	Industry Name	Sector	Industry Code	Industry Name
B	7	Mining of metal ores	C	32	Other manufacturing
B	8	Other mining and quarrying	C	33	Repair and installation of machinery and equipment
B	9	Mining and quarrying n.e.c.	D	35	Electricity, gas, steam and air conditioning supply
C	10	Manufacture of food products	E	36	Water collection, treatment and supply
C	11	Manufacture of beverages	E	37	Sewerage
C	12	Manufacture of tobacco products	E	38	Waste collection, treatment and disposal activities; materials recovery
C	13	Manufacture of textiles	E	39	Remediation activities and other waste management services
C	14	Manufacture of wearing apparel	E	46	Wholesale trade, except of motor vehicles and motorcycles
C	15	Manufacture of leather and related products	H	49	Land transport and transport via pipelines
C	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	H	50	Water transport
C	17	Manufacture of paper and paper products	H	51	Air transport
C	18	Printing and service activities related to printing	H	52	Warehousing and support activities for transportation
C	19	Manufacture of coke and refined petroleum products	H	53	Postal and courier activities
C	20	Manufacture of chemicals and chemical products	J	58	Publishing activities
C	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	J	59	Motion picture, video and television programme production, sound recording and music publishing activities
C	22	Manufacture of rubber and plastic products	J	60	Programming and broadcasting activities

C	23	Manufacture of other non-metallic mineral products	J	61	Telecommunications
C	24	Manufacture of basic metals	J	62	Computer programming, consultancy and related activities
C	25	Manufacture of fabricated metal products, except machinery and equipment	J	63	Information service activities
C	26	Manufacture of computer, electronic and optical products	K	64	Financial service activities, except insurance and pension funding
C	27	Manufacture of electrical equipment	K	65	Insurance
C	28	Manufacture of machinery and equipment n.e.c.	K	66	Activities auxiliary to financial services and insurance activities
C	29	Manufacture of motor vehicles, trailers and semi-trailers	M	71	Architectural and engineering activities; technical testing and analysis
C	30	Manufacture of other transport equipment	M	72	Scientific research and development
C	31	Manufacture of furniture	M	73	Advertising

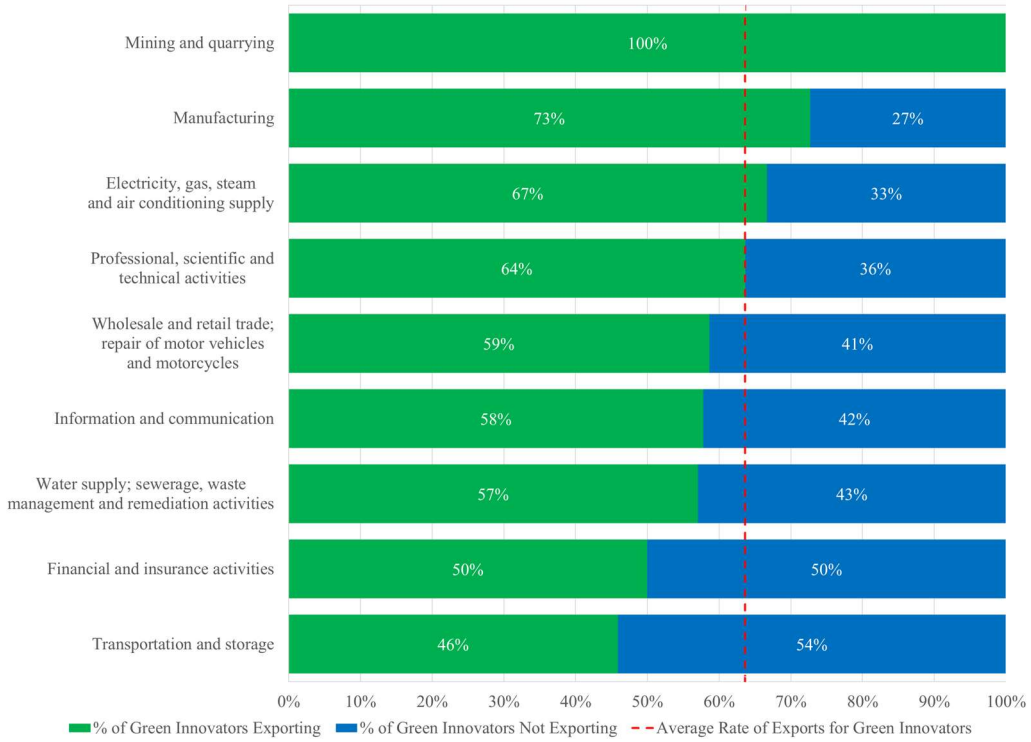
Source: NACE Rev. 2 Statistical Classification of Economic Activities in the European Communities, Eurostat, Luxembourg: Office for Official Publications of the European Communities, 2008. https://ec.europa.eu/eurostat/web/nace-rev2/overview.

Figure A1: Export participation of green innovators with product innovation by sector



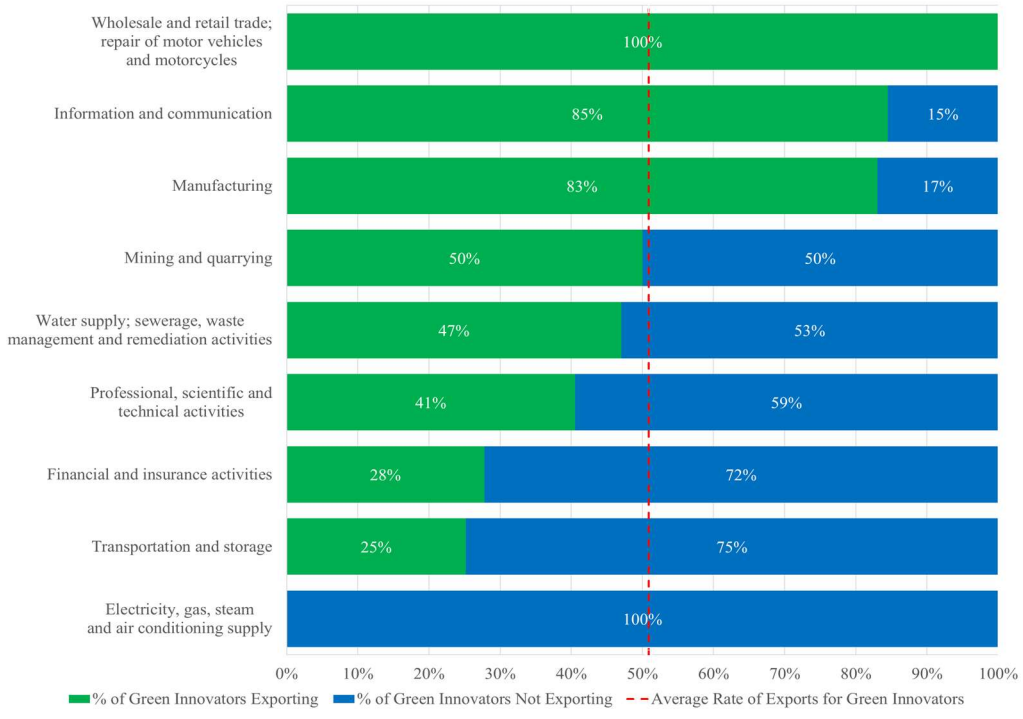
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A2: Export participation of green innovators with process innovation by sector



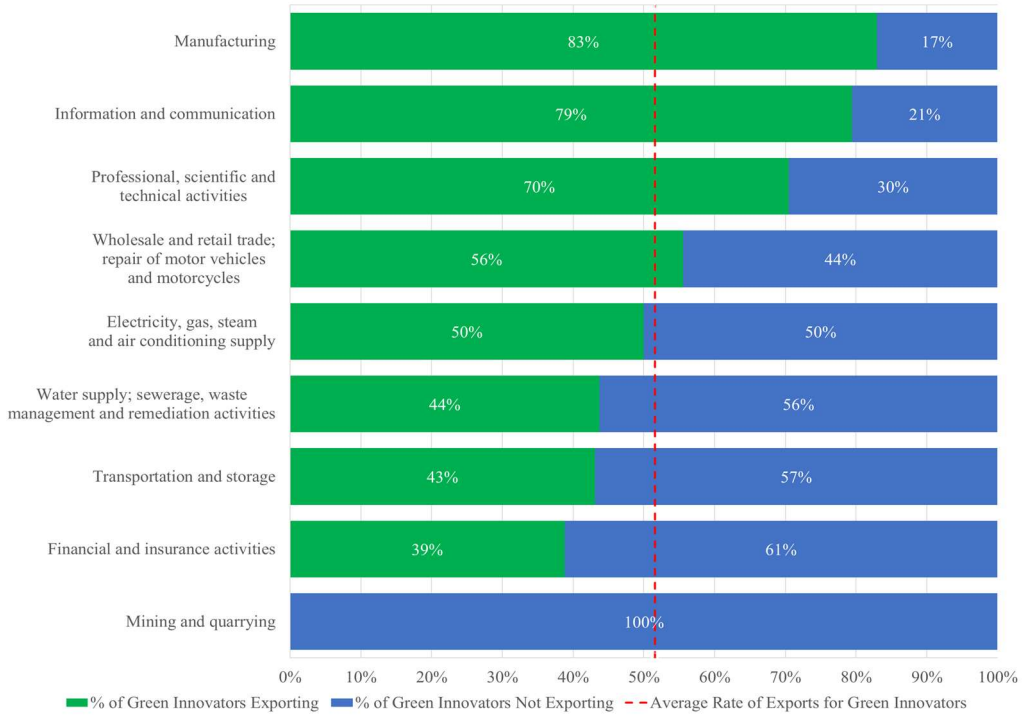
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A3: Export participation of green innovators with organizational innovation by sector



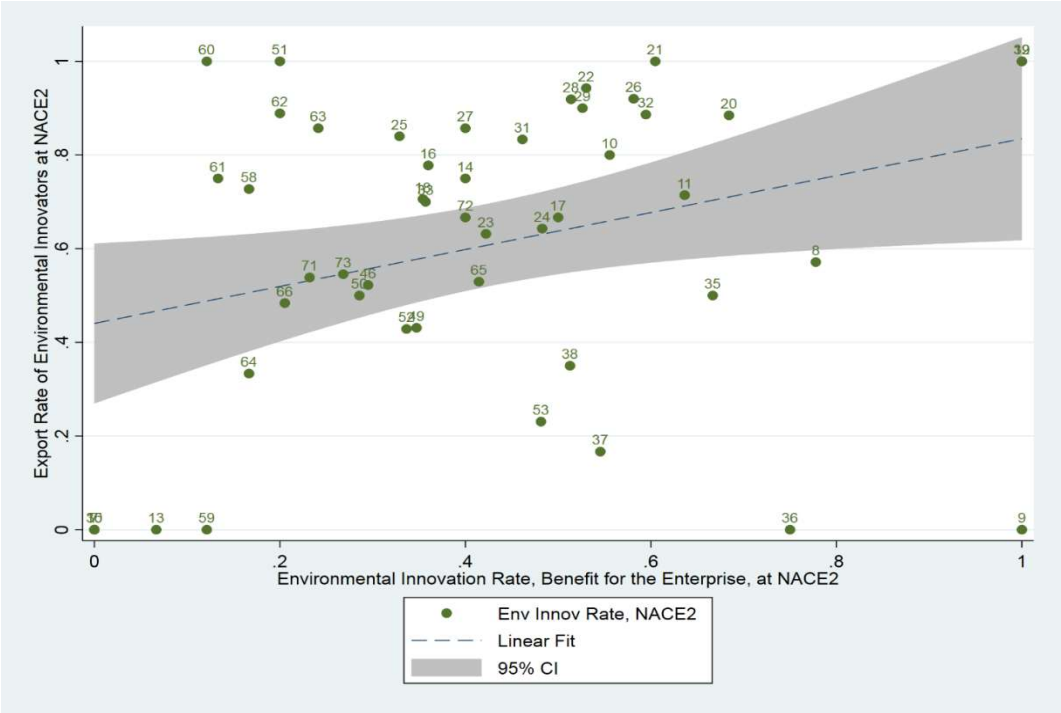
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A4. Export participation of green innovators with marketing innovation by sector



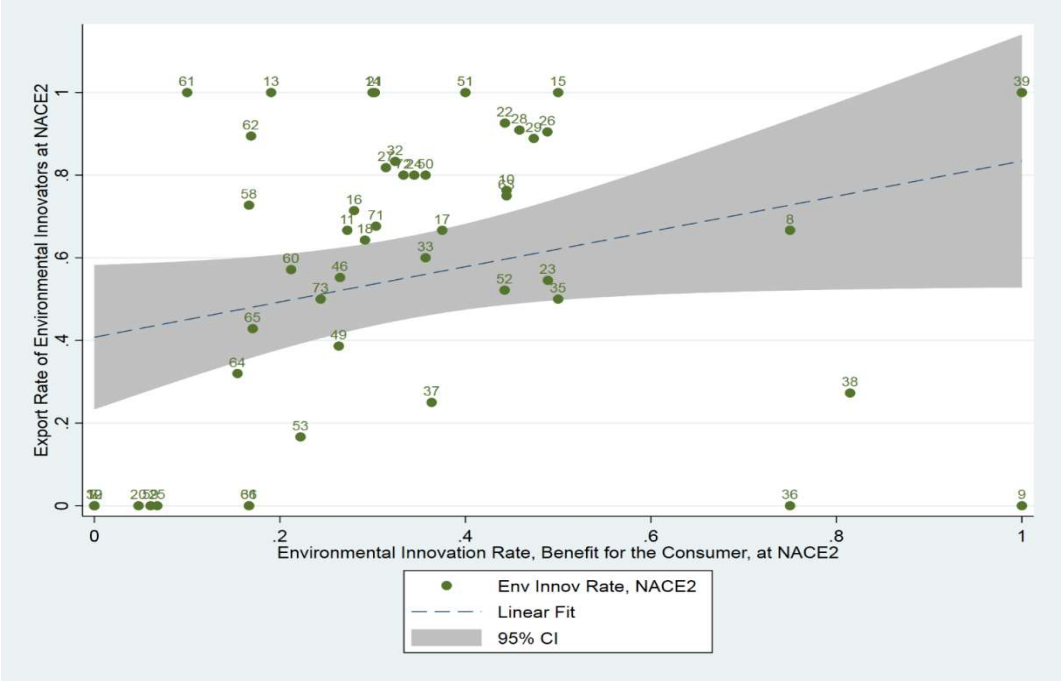
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A5: Correlation of green innovation rates and export participation rates by industry, innovations with environmental benefits for the enterprise, 2012-2014



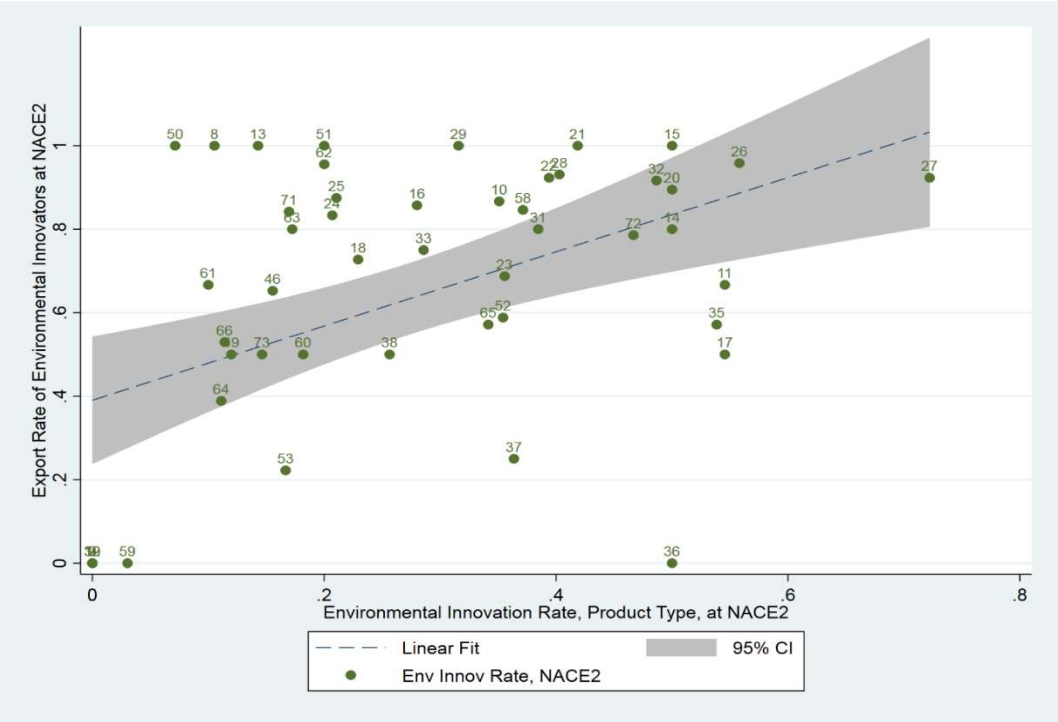
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A6: Correlation of green innovation rates and export participation rates by industry, innovations with environmental benefits for the consumer, 2012-2014



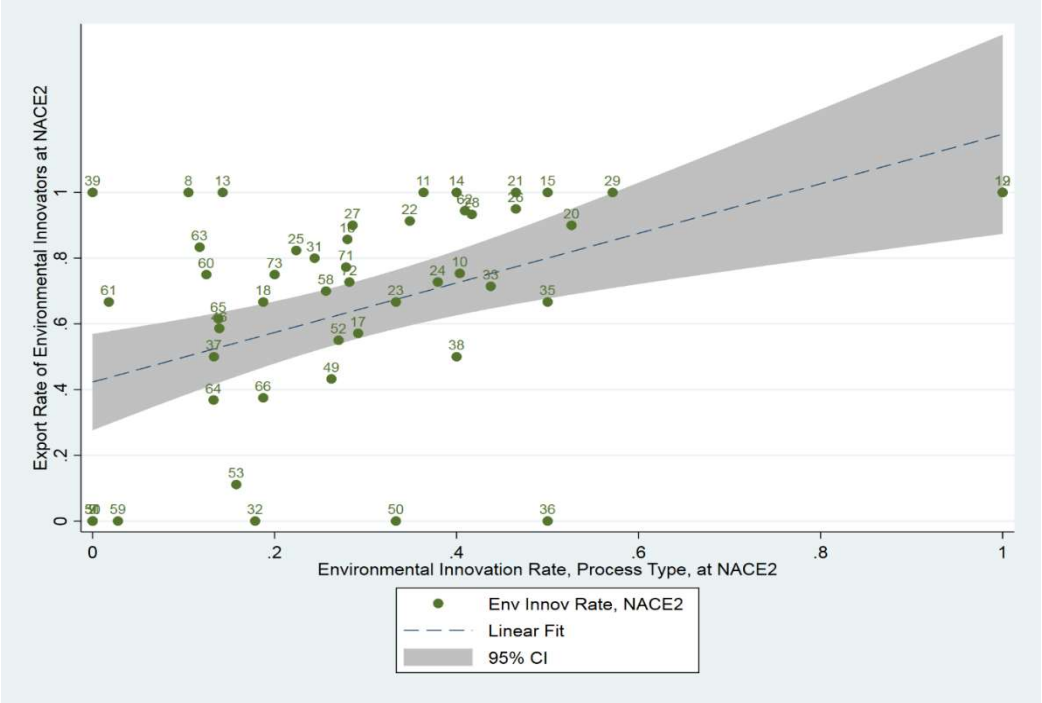
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A7: Correlation of green innovation rates and export participation rates by industry, product innovations with environmental benefits, 2012-2014



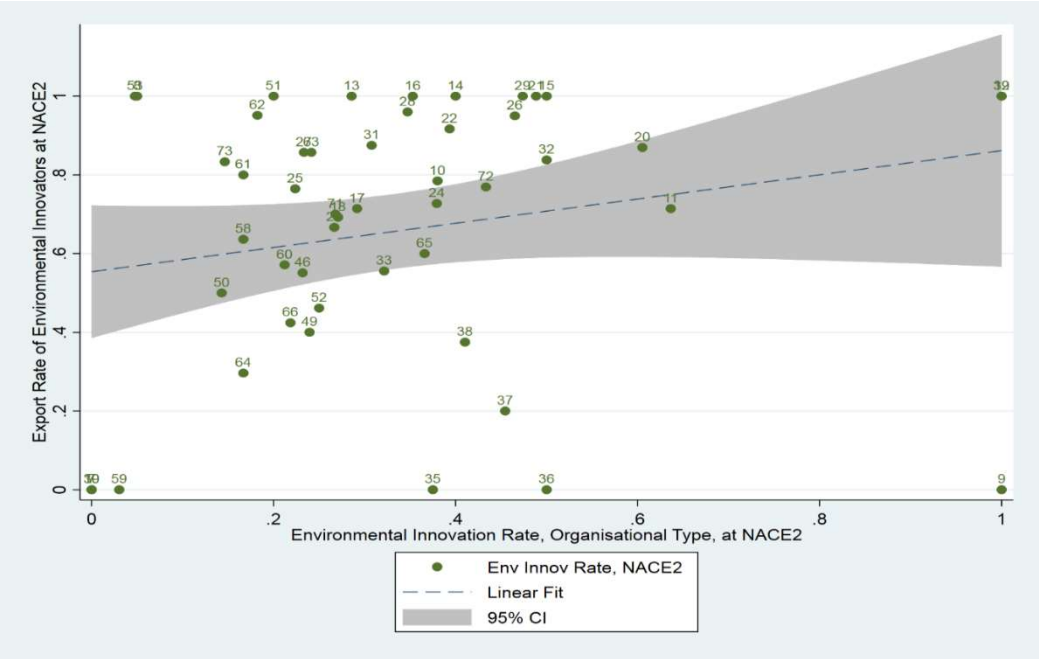
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A8: Correlation of green innovation rates and export participation rates by industry, process innovations with environmental benefits, 2012-2014



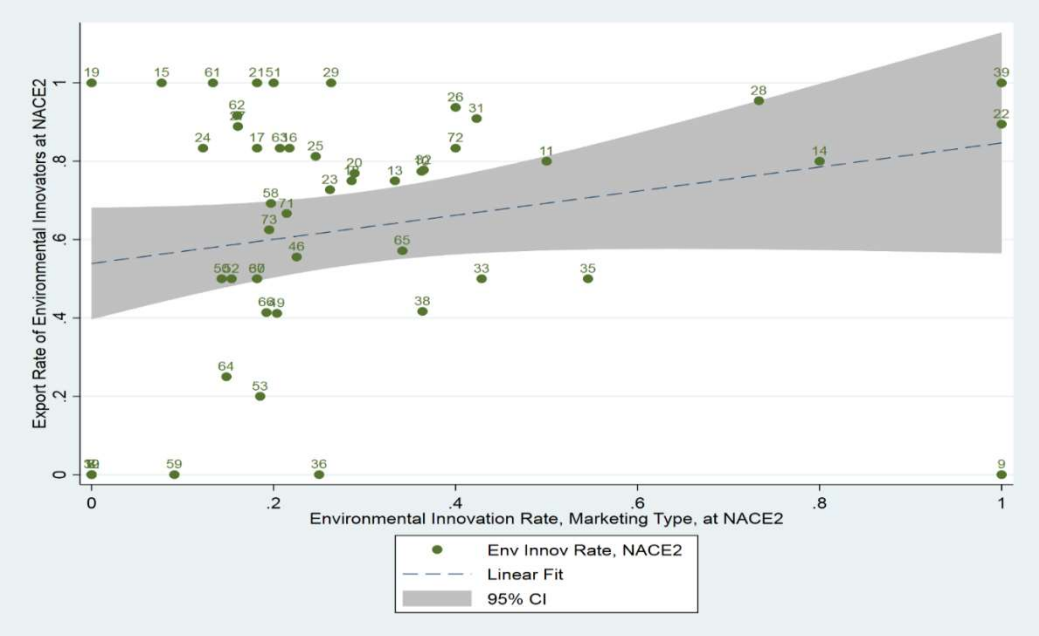
Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A9: Correlations of green innovation rates and export participation rates by industry, organizational innovations with environmental benefits, 2012-2014



Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.

Figure A10: Correlation of green innovation rates and export participation rates by industry, marketing innovations with environmental benefits, 2012-2014



Source: Authors' elaboration based on data from the Community Innovation Survey 2014, Central Statistics Office, Ireland.