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Firms' green investments: What factors matter?☆

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ABSTRACT

This paper examines factors underlying firms' investments in environmental protection (green investments). Using micro data from Ireland's industry sector over the period 2008–2016, we analyse a range of factors internal to firms such as firm characteristics, as well as external factors including environmental regulations, competition and spillover effects from other firms' green investment decisions. Our results indicate that larger firms, importers, and firms which are part of an enterprise group are more likely to invest in equipment for pollution control and in equipment linked to cleaner technologies. Within industry competition incentivizes firms to invest in equipment linked to cleaner technologies. Further, our results indicate that the propensity of firms to invest in equipment for pollution control are higher for more energy-intensive firms. Finally, our results uncover significant positive spillover effects from firms with green investments in the same industry or the same region on firms' decisions to invest on environmental protection.

1. Introduction

The transition to a climate-neutral economy and a more sustainable long-term economic growth require private firms to invest in environmental protection and green technologies. Recent contributions to the literature suggest that green technologies not only improve environmental quality, but they also contribute to firms' competitiveness and growth (Porter and van der Linde, 1995, Molina-Azorín, 2009, Iraldo et al., 2009, and López-Gamero et al., 2010, among others). However, the proportion of firms engaged in green investments appears to be low. For example, in the case of Ireland's industry sector, over the period 2008–2016, less than 10% of firms invested in environmental protection in a given year. While a larger proportion of firms (around a quarter) have current expenditures on environmental protection, these expenditures have been found to be the least innovation inductive (McInerney et al., 2019). In Slovenia, over the period 2005–2011, the share of firms with investments in energy efficiency and in cleaner technologies was on average 4.9% in the same year, lower than the corresponding share of firms with other investments such as replacement of old equipment, automation and mechanisation and the introduction of new products (Hrovatin et al., 2016).

Understanding what determines firms' decisions to invest in environmental protection is important for the design of policy measures aimed at facilitating firms' engagement in green investments and at improving environmental quality and resource efficiency. Existing evidence on factors that influence firms' decisions to engage in green investments is still limited. Previous empirical studies have often focused on a limited range of factors, a single industry or on aggregated green investments. While existing evidence is relevant and important, in our view, to fully understand the effects of such factors on firms' decisions to invest in "end-of-pipeline" equipment or green innovation, further more systematic and granular evidence is needed.

To fill this gap, this paper provides novel evidence on factors internal and external to firms that influence their decisions to engage in green investments. To this purpose, we use micro-data from Ireland's industry sector over the period 2008–2016. Factors internal to the firm include

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size, ownership, age, sector of activity, energy intensity, engagement in international trade, supply chain links, skills, and other investments in tangible and intangible assets. Factors external to the firms include environmental regulations, competition and spillover effects from other firms with green investments in the same industry and the same region. We further investigate if the country of origin of foreign investors played a role on firms' investment decisions over and above foreign-ownership. This question is relevant given the variation of environmental regulations across countries in the world.

The novelties of our contribution to the literature are threefold. Firstly, we add to the existing literature in that we design and use a unified econometric framework to analyse the effects of both internal and external factors on firms' decisions to invest in environmental protection. Secondly, using this unified analytical framework, we examine spillovers on firms' decisions to engage in green investments from other green investors in the same industry and the same region. To the best of our knowledge, potential spillover effects in the context of firms' green investments have not been considered in the previous studies. Thirdly, we account for a potential heterogeneous investment behavior with respect to firms' decisions to engage in two distinct green investments: investment in equipment for pollution control and investment in equipment linked to cleaner technologies.

Our results indicate that such internal and external factors have heterogenous effects on firms' decisions to engage in different types of green investment. Overall, larger firms, and firms which are part of an enterprise group are more likely to invest in equipment for pollution control and in equipment linked to cleaner technologies. Further, we find that importers are more likely than the rest of the firms to engage in green investments. This result is consistent with existing evidence on the role of imports as a channel for technology diffusion (see for example Keller, 2004 for a review of the international evidence) and it might reflect the fact that Ireland's imports are predominantly from advanced economies. To the best of our knowledge, this evidence is novel in the context of firms' green investments.

Our results also indicate that local firms are more likely to engage in both types of green investments than foreign-owned firms. This result might reflect the fact that these foreign affiliates have already adequate equipment for pollution control and cleaner technologies and there is no need for further investment. Our findings showing that foreign affiliates are less likely than local firms to invest in environmental protection are consistent with previous evidence from Ireland (Haller and Murphy, 2012) and from other countries (Aden and Kyu-Hong, 1999 for South Korea; Collins and Harris, 2005 for the United Kingdom). Further, we find that our results are mainly driven by US-based multinationals which are more energy efficient than local firms. The energy intensity of firms' production is positively linked to the propensity to invest in equipment for pollution control but not to that to invest in equipment linked to cleaner technologies.

Consistent with the literature on competition and innovation, we find that within industry competition incentivizes firms to invest in cleaner technologies as such an investment leads to innovation and may increase firms' efficiency and competitiveness. This result is consistent with earlier evidence of the pro-innovation effects of competition (Aghion et al., 2001; Aghion and Griffith, 2005). However, within industry competition does not seem to have significant effects on firms' propensity to invest in equipment for pollution control. Further, our results indicate that environmental regulations do not appear to have a statistically significant impact on the decision of firms to invest in equipment for pollution control or in equipment linked to cleaner technologies. However, firms may incur additional operational costs to comply with environmental regulations, and these costs are reflected in their current expenditures. While the focus of this paper is on investment in environmental protection, an analysis of factors underlying firms' current expenditures on environmental protection is presented in a separate Online Appendix.

Finally, our results uncover significant positive spillover effects from firms with green investment in the same industry or the same region on firms' propensity to invest in environmental protection. One possible channel for such spillovers is that firms can learn from their peers, especially when the benefit of investing in environmental protection is uncertain. Such risks could be eliminated by observing other firms' investment behaviour. Another reason might be that managers' awareness of protecting the environment could be enhanced by observing other firms' investment decisions, and therefore, this increases firms' incentives to invest.

Our research adds to and connects three literature strands. Firstly, we add to the literature strand focused on the role of firm heterogeneity on firms' engagement in green investments. Using Irish data for 2006 and 2007, Haller and Murphy (2012) find that larger firms, exporters, and energy-intensive firms were more likely to invest in environmental protection, while foreign-owned firms were less likely to invest. They also find that conditional on investing, larger and older firms tend to invest more. Using data from the chemical industry in the UK, Collins and Harris (2005) find that the probability of investment in environmental protection and the investment intensity are different for local firms, EU-owned, and US-owned firms. The role of green management practices has been found to be an important internal factor for firms' engagement in green investments (De Haas et al., 2020). In relation to the role of management on firms' engagement in green investment, Montalvo Corral (2008) finds that results are different when survey data on managers' willingness to invest (expressed-preference) are used and when data on the actual investment in green technology (revealed--preference) are used. In comparison with these studies, we analyse a broader range of firm characteristics and uncover additional internal factors underlying firms' engagement in green investments such as: firms' engagement in importing activities, export destinations, intra-firm transactions and a firm's position in supply chains, and firms' investment in intangible assets.

Secondly, our research paper adds novel evidence to the literature focused on the role of factors external to firms such as environmental regulations and competition that are widely thought to increase firms' incentives to invest in environmental protection. Recent reviews of this literature are provided by Montalvo Corral (2008), Murovec et al. (2012), Cagno et al. (2013) and Hrovatin et al. (2016). Using survey data on small and medium size manufacturing firms in northern Mexico, Montalvo Corral (2003) finds that firms' willingness to invest in cleaner technologies are correlated with social norms, perceived economic risk and technological capabilities.

The existing empirical evidence on the effects of environmental regulations on firms' engagement in green investments is far from conclusive. Anderson et al. (2011) analyse Irish firms in manufacturing which took part in the pilot phase of the European Union Emissions Trading System (EU ETS). They find that a significant proportion of firms (48%) reported that they would consider adopting new technologies and equipment that are more environment-friendly, and around three quarters of firms reported they had already made behavioural changes in this respect. However, using data from the Census of Industrial Production (CIP), Haller and Murphy (2012) find that only 5.4% of firms invested in equipment for pollution control. Moreover, they find that the effect of the EU ETS on the propensity of firms to invest in environmental protection was insignificant or negative, in contrast to the expected effect. The insignificant effect of regulations on investment in environmental protection has also been found in the cases of Italy (Borghesi et al., 2015) and Lithuania (Jaraite and Di Maria, 2016).

One possible explanation for these mixed results could be that environmental regulations are designed primarily to prevent air pollution but not necessarily to incentivize firms to invest in green technologies. In contrast, competition may have a more pronounced effect on promoting firms' investment in green technologies. Furthermore, as outlined in the literature, green innovation is risky, as the cost is high while the payback is uncertain. Taken these considerations into account, we exploit existing data on firms' engagement in investment in equipment for pollution control and in investment for cleaner technologies and allow in our analysis for heterogenous effects of environmental regulations and competition on these two different types of firms' green investments.

Thirdly, our paper adds novel evidence to the literature on technology diffusion and spillovers. The existence of such knowledge spillovers from early adopters has been formalized in models of new technology diffusion (Mansfield, 1963; Stoneman, 2002). Further, it has been shown that knowledge spillovers are geographically localized because they decline when the distance between firms increases (Jaffe et al., 1993; Keller, 2002). Proximity to early adopters has been found to facilitate such learning effects in the context of the diffusion of new technologies (Baptista, 2000; Battisti and Stoneman, 2003; Battisti et al., 2007) and of innovation (Audretsch and Feldman, 1996). Haller and Siedschlag (2011) provide evidence on knowledge spillovers from firms within the same industry and within the same region in the context of the adoption of information and communication technologies (ICT) across firms in Ireland. Leary and Roberts (2014) find that peer effects matter when firms decide on their financial strategies and corporate capital structures. Duflo and Saez (2002) and Munshi (2004) provide evidence on spillover effects in the context of individual decisions.

Kemp and Volpi (2008) outlined some stylized facts about the diffusion of green technologies. On the basis of the reviewed existing evidence, they argue that the diffusion of green technologies is slow and complex. Not only it requires knowledge transfer, but it also requires adopters' own learning-by-doing process and innovation. Xin-gang et al. (2019) find that the spillover effects of foreign direct investment (FDI) from home to host country will facilitate the convergence of energy intensity across different regions in China. Zhou et al. (2019) find that outward FDI may also have spillover effects on green technologies in the home country.

To the best of our knowledge, knowledge spillovers from green investors on firms' investments in environmental protection have not been analysed so far. We examine and uncover significant positive spillover effects from firms with green investments in the same industry or the same region on firms' propensity to invest in environmental protection.

The remainder of this paper is organized as follows. Section 2 describes the data and Section 3 presents the econometric methodology and model specifications. Section 4 discusses the econometric results. Finally, Section 5 concludes.

2. Data

2.1. Descriptive analysis

The data we use is from the Census of Industrial Production (CIP) Survey carried out by Ireland's Central Statistics Office (CSO). The survey covers enterprises in the industry sector with three and more persons engaged. According to the CSO (2016) enterprises with three and more persons engaged account for 97% of the total turnover in the industry sector in 2016. The response rate was 68% and enterprises that responded to the survey represented 92% of total employment. Therefore, the CIP data has a good representation of Ireland's industry sector.

Our analysis focuses on the manufacturing and utilities sector. We analyse information on investment in equipment for pollution control (PC) and investment linked to cleaner technologies (CT). These two investment variables are obtained from reported information on changes in capital assets. However, not all enterprises are required to provide details on their environment-related investment. The CIP survey has two questionnaire forms: a short version of the questionnaire is sent to firms with less than 20 persons engaged (Form C) to collect information such as turnover, total persons engaged, change in total capital assets, foreign or local firm and a few additional variables. A longer version of the questionnaire (Form F) is sent to firms with 20 and more persons engaged to collect more detailed information including investment in and spending on environmental protection. Firms which responded to Form F represent around 49% of the total number of enterprises in the data.

However, not responding to Form F does not mean the enterprise does not have investment in environmental protection. This censoring of data may potentially induce a selection bias if we only consider enterprises that responded to Form F (thereafter, Form F firms). To account for this potential selection bias, we use a two-step Heckman model.

We exclude firms that have negative gross value added (around 2% of total observations). We also exclude enterprises with less than 3 persons engaged. The resulting sample consists of 16,199 firm-year observations over the period 2008–2016. The rest of the section provides some descriptive analysis based on Form F firms since information on green investment in environmental protection is not collected for firms which responded to Form C.

Fig. 1 shows the rates of green investment by industry, where an industry is defined as the 2-digit NACE Rev.2 classification. On average, only 3.9% of firms invested in equipment for pollution control in a given year and only 3.7% of firms invested in equipment linked to cleaner technologies. These results are similar to the investment rates found by Haller and Murphy (2012) using data for 2006 and 2007 (5.4% for investment in plant and equipment for pollution control) and McInerney et al. (2019). However, the investment rates are much lower than figures reported by Anderson et al. (2011). One possible reason is that managers' willingness to invest (expressed-preference) may not always be consistent and comparable to their revealed investment actions (Montalvo Corral, 2008).

In comparison to manufacturing, the energy industry (NACE Rev 2. code: 35) has a much higher rate of investment in equipment linked to cleaner technologies, around 20% in the analysed data set. This result is not surprising given the large extent of regulations on emissions in place in this sector.

Fig. 2 shows the proportion of firms that invest in environmental protection by region of location (NUTS 3). The rates of investment in equipment for pollution control range from 2.7% (Midlands) to 5.3% (South-East) while the rates of investment in equipment linked to cleaner technologies range from 2.6% (West) to 5.2% (Midlands).

The overall trend of the proportion of firms that invest on environmental protection is presented in the left panel of Fig. 3. The rates of green investment are fairly stable over the analysed period. Among all firms, the rate of investment in equipment for pollution control or in equipment linked to cleaner technologies is lower than 5%. Slightly more firms invest in cleaner technologies between 2010 and 2012 comparing to other years.

As the investment rates are flat over time, we further investigate if firms' investment behaviour is persistent over time. On the right panel in Fig. 3, we show the number of firms by the first year we observe a positive investment in environmental protection during the analysed period. The figure indicates that for the majority of firms that ever invest during the analysed period, we observe them investing in 2008, while there are very few new investors joining green investment in later years. For example, 48 unique firms in our dataset have already started investing in pollution control in 2008, while only four new firms started to spend in 2009. In 2013, this number further decreased to one. The descriptive analysis suggests that firms' investment on environmental protection are highly persistent in that firms that had spent on 2008 are more likely to spend in the following years. We will test this pattern formally in our econometric analysis.

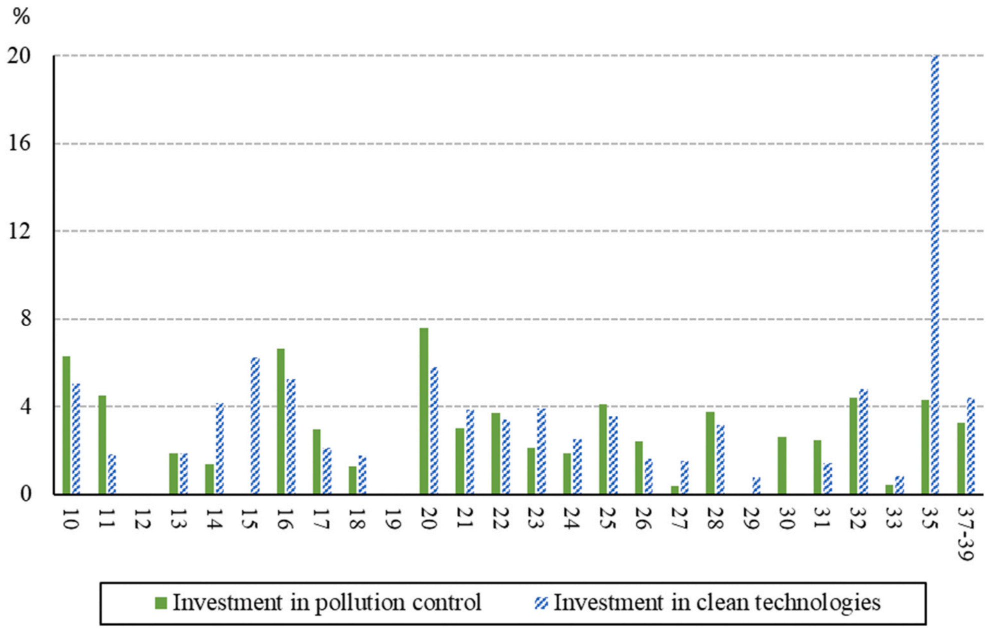

Fig. 1. Green investment rates by industry, 2008–2016. *Source*: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland. Note: The NACE Rev. 2 classification codes are as follows: 10 Manufacture of food products; 11 Manufacture of beverages; 12 Manufacture of tobacco products; 13 Manufacture of textiles; 14 Manufacture of wearing apparel; 15 Manufacture of leather and related products; 16 Manufacture of wood and products of wood and cork; except furniture; manufacture of articles of straw and plaiting materials; 17 Manufacture of paper and paper products; 18 Printing of reproduction of recorded media; 19 Manufacture of coke and refined petroleum products; 20 Manufacture of chemicals and chemical products; 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations; 22 Manufacture of rubber and plastic products; 23 Manufacture of other non-metallic mineral products; 24 Manufacture of basic metals; 25 Manufacture of fabricated metal products, except machinery and equipment; 26 Manufacture of computer, electronic and optical products; 27 Manufacture of electrical equipment; 28 Manufacture of machinery and equipment n.e.c.; 29 Manufacture of motor vehicles, trailers and semi-trailers; 30 Manufacture of other transport equipment; 31 Manufacture of furniture; 32 Other manufacturing; 33 Repair and installation of machinery and equipment; 35 Electricity, gas, steam and air conditioning supply; 37 Sewerage; 38 collection, treatment and disposal activities; materials recovery; 39 Remediation activities and other waste management services.

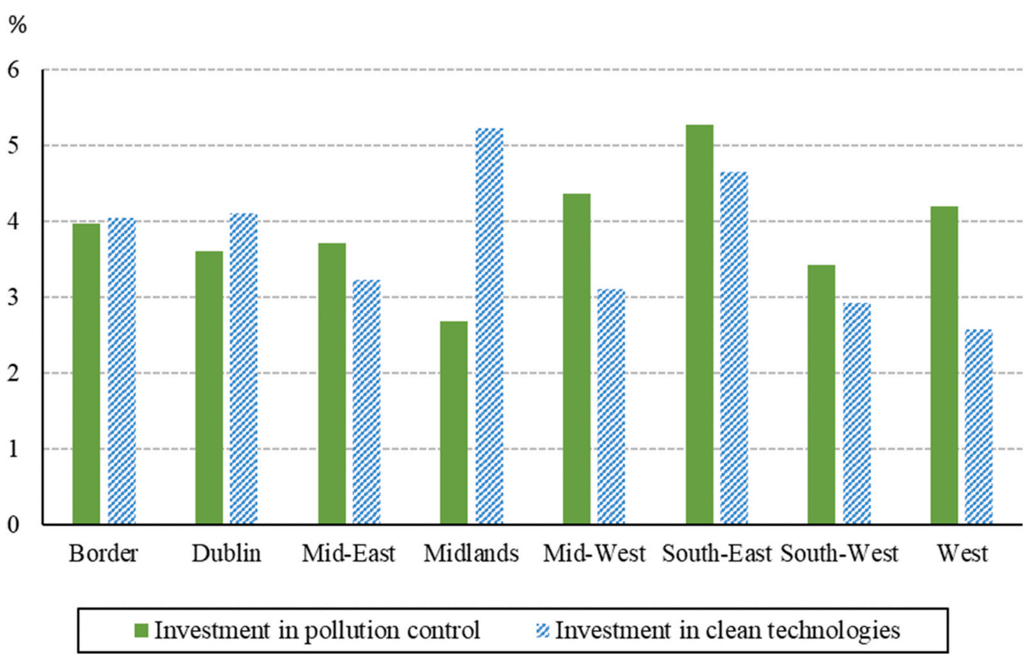

Fig. 2. Green investment rates by region, 2008–2016. *Source*: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

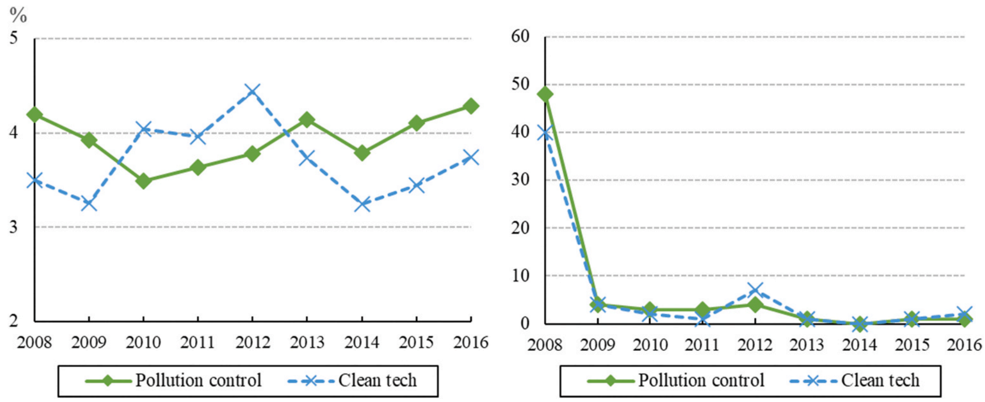

Fig. 3. Green investment rate in all firms by year (left) and distribution of firms by the first year with positive green investment in the data set (right). *Source*: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

2.2. Key variables

The key variables used in our analysis include firm-specific characteristics, environmental regulations, market structure and peer firm characteristics. Previous studies have found that larger firms are more likely to invest in environmental protection and they tend to invest more. In addition to firm size (measured by gross value added), we consider the following firm-specific characteristics: firms' age, energy intensity in production (the ratio of fuel purchased over gross value added), wage (as a proxy for worker skills) and labour productivity (gross value added over number of persons engaged). Firms' capital and current expenditures on other fixed assets are also important. We explicitly compute investment in intangibles intensity (capital and current expenditures in intangible assets over gross value added), and investment in other tangible assets intensity (capital expenditures on tangible assets, excluding capital expenditures on environmental protection over gross value added).

Based on previous evidence, foreign ownership and the country of origin of foreign investors affect a firm's investment decision (Collins and Harris, 2005). Further, Haller and Murphy (2012) find that exporters are more likely to invest in environmental protection, suggesting firms' participation in international trade might affect their green investment decisions. In comparison to Haller and Murphy (2021), in addition to exporting, we also consider importing as an underlying factor of firms' green investments. Given that imports have been found to be an important channel of technology diffusion (Keller, 2004), we include in the model specifications a binary variable to distinguish importers from the rest of the firms. In addition, we consider intra-firm transactions and firms' position in the supply chain. In particular, we consider intermediate materials transferred to affiliates. Downstream firms tend to have a higher percentage of materials transferred from affiliates, which may influence their decision to invest in environmental protection.

Furthermore, in addition to binary variables for foreign ownership and exporting, in one of our model specifications, we also include more detailed information on the origin of foreign investors and destinations of firms' exports. We separate the location of a firm's headquarter into six categories: local (Ireland), the UK, the Euro zone, the rest of the EU, the US and the rest of the world (ROW). Local firms are taken as the reference category. We also separate the country (region) where firms export to using the above-mentioned export destinations. This could help us to understand firms' investment behaviour by firm group.

Market structure could be another factor that influences firms' investment in environmental protection, as competition may incentivize firms to invest. To capture market structure, we use the share of the firm's output in the corresponding industry output, and a measure of market concentration, namely the Herfindahl-Hirschman Index (HHI) of an industry j defined at 2-digit NACE Rev. 2 as follows:

$$HHI_j = \sum_{i\in j} s_{ij}^2,\ s_{ij} = \frac{x_{ij}}{\sum_{i\in j} x_{ij}} \tag{1}$$

x_{ij} denotes the output of a given firm i in industry j.

As firms in the energy industry are more likely to invest in equipment linked to cleaner technologies than other industries, a dummy for this sector is included in the model specifications. Another important factor influencing firms' decisions to invest in environmental protection is the presence of environmental regulations. In Ireland, two regulations on environmental protection are in place. The first is the EU wide emissions trading system (EU ETS), which covers more than 11,000 power stations and industrial plants in 31 countries. In Ireland, around 100 installations are under the EU ETS.[1] However, the matching of firms having these installations to the CIP data is not possible as the CIP data are anonymised. Therefore, we consider that a firm is covered by the EU ETS if it belongs to one of the following sectors: Pulp and Paper (17), Petroleum and Coke (19), Chemicals (20), Non-metallic minerals (23) and Basic Metals (24). This proxy variable has also been used in other studies (see for example, Dechezleprêtre et al., 2018; Borghesi et al., 2015).[2] Another relevant environment-al regulation is the Integrated Pollution Control (IPC) program, which aims to reduce emissions to air, water, and land, and increase energy efficiency.[3] Firms with specific activities and with output above certain thresholds are required to get an IPC license before commencing any activity. However, because of the data matching issue mentioned above, we cannot consider the effect of the IPC on firms' propensity to invest in environmental protection.

Further, as shown in the descriptive analysis, firms' decisions to invest in environmental protection are highly persistent that most firms that invested in 2009 and onwards are firms that have invested in 2008,

[1] This information is available from the EPA web site: https://www.epa.ie/climate/emissionstradingoverview/.

[2] Borghesi et al. (2015) construct an indicator of 'policy stringency' based on the emission cap introduced by the EU ETS. They argue that firms may be more likely to invest in environmental protection projects if they have a higher emission to cap ratio, because they face stronger pressure to reduce emissions. However, this measure is difficult to construct in practice. The ETS allowance is assigned to each country by the European Commission based on emission data provided by member countries, and a country decides the amount for each installation. In Ireland, the allowance is given to each participating installation based on emission data collected in 2007 and 2008. One difficulty to replicate the process is that the exact cap is not possible to match to each firm. Therefore, we cannot consider this variable.

[3] EPA website: https://www.epa.ie/licensing/ipc/.

with only a few new investors in the later years. To account for this persistency, we include in the estimated model a categorical variable that equals 1 if a firm has invested in environmental protection in 2008.

To estimate spillover effects, we construct peer firm participation rates and peer firm characteristics. Peer effects are generated in two ways. First, for a given firm *i* we consider that firms in the same NACE 2-digit industry are its peers, and we construct peers' average probability to invest and average characteristics for these firms by excluding firm *i*. This approach is used to uncover whether a firm's decision to invest would be influenced by other investors in the same sector. Second, we repeat this exercise, but consider for a given firm *i* its peers in the same (NUTS 3) region. We expect that a firm's decision to invest would be affected by other firms in the same region, as they are close to each other geographically so that they may have more frequent interactions and learning processes. As the average probability to invest is very small in general, we multiply the figures by 100 to facilitate reading.

As discussed before, the majority of variables are only available for firms which responded to Form F. To estimate the selection part of the two-step Heckman model, we use variables that are available for all firms including: gross value added, total investment in tangible assets, a dummy that indicates if the firm has more than 20 persons engaged, as well as whether it is an Irish or a foreign-owned firm. All monetary variables are in constant 2015 prices obtained by using production price indices by industry. Detailed descriptions of all variables and summary statistics are given in Table A1 in the Appendix.

3. Econometric methodology

3.1. Baseline model specifications

We first consider which types of enterprises are more likely to invest in environmental protection. Second, we consider whether a firm's decision is influenced by the investment behaviour of other firms with green investments in the same industry or in the same region.

Since only firms responding to the CIP survey Form F report their investment in environmental protection, we use the Heckman selection model to correct for this data censoring. In our baseline model, we employ a system of two equations of the following form. In the first stage, we estimate a firm's probability to fill the CIP survey Form F, and in the second stage, we estimate their probability to invest conditional on filling Form F:

$$\text{Selection: } f_{it} = 1\left[\alpha_1 + X_{2it}\beta + I_j + R_r + Y_t + v_{it} > 0\right] \quad (2)$$

$$\text{Outcome (1): } y_{it} = 1\left[\alpha_2 + X_{1it}\mu + Y_t + u_{it} > 0\right] \quad (3)$$

$$\text{Outcome (2): } y_{it} = 1\left[\alpha_2 + X_{1it}\mu + \gamma\widehat{\mathrm{E}_{-i}}(y_t|g) + Y_t + u_{it} > 0\right] \quad (4)$$

where f_{it} is a binary variable that indicates if firm *i* answers Form F in year *t*. Similarly, y_{it} is a binary variable that indicates if firm *i* invests in environment protection in year *t*. y_{it} is only observed when $f_{it} = 1$. X_s are the variables of interests and β, μ are coefficients associated with them. Specifically, X_1 are variables that are observed for the full sample. I_j, R_r and Y_t are industry, region, and year fixed effects, respectively. α_1 and α_2 are constants and v_{it}, u_{it} are the error terms in the selection and outcome equation.

We then investigate whether the behaviour of peer firms matters for firms' decisions to invest in environmental protection. We investigate two types of peer effects: from firms in the same industry, and from firms in the same region. The selection equation is the same as in the model described by Eq. (2), while for the outcome equation, we further include the expected investment rate $\widehat{\mathrm{E}_{-i}}(y_t|g)$, where g is the peer group. This expected investment rate is the average of *other* firms' investment decision in the same peer group. In this specification, the outcome equation is Eq. (4).

3.2. Endogeneity

$\widehat{\mathrm{E}_{-i}}(y_t|g)$ is likely to be endogenous, as other firms' investment decisions in the same peer group may be reversely affected by firm i's investment decisions. Therefore, we use instrumental variables, Z_{it}, and assume a linear correlation between $\widehat{\mathrm{E}_{-i}}(y_t|g)$ and Z_{it}: $\widehat{\mathrm{E}_{-i}}(y_t|g) = Z_{it}\eta + w_{it}$, where w_{it} is the error term.

A common approach is to use average characteristics of peer firms as instruments (see for example, Duflo and Saez, 2002; Case and Katz, 1991). These instruments are valid if peer firms' characteristics are not affected by firm *i*'s investment decision. The primary instrument we use is the proportion of local firms in a peer group (peer_s_local and peer_r_local). As we will see in the results section, a local (Irish-owned) firm is more likely to invest in environmental protection than foreign-owned firms and thus, a higher proportion of local firms in a peer group also correlates with a higher average investment rate. Importantly, other firms' ownership is very unlikely to be affected by a given firm's decision to invest in environment protection, so this instrument is likely to be exogenous to the system.

While the proportion of local firms appears to be a valid and strong instrument for an industry peer effect, this variable is much weaker when used as an instrument for the spatial peer effect. To improve on this, we use additional instruments for the spatial peer effect: the proportion of exporters in group of the peer firms in the same region (peer_r_exporter), the proportion of importers in the group of peer firms in the same region (peer_r_importer),[4] and the average energy intensity in the group of peer firms in the same region (peer_r_fuel).

If our instruments are valid, we may conclude that peer effects are present if the parameter γ is positive (negative) and significantly different from zero. These results would suggest that peer firms' green investment will increase (decrease) a firm's probability to invest in environmental protection.

The estimating procedure is as follows. We first estimate the selection equation using a probit model and compute the Inverse Mill's Ratio (IMR) for the full sample. We then estimate the outcome equation with an IV probit model with IMR as a regressor to correct for selection bias. Since IMR is generated from the first stage, we bootstrap standard errors (with 200 replications). As suggested by Wooldridge (2010), a standard *t*-test is used to test the significance of the selection bias.

4. Results

4.1. Baseline model results

We first present the results from the baseline Heckman model in Table 1. The left panel of the table shows the results of the outcome equation. For each dependent variable of interest, we report results from two specifications. The first column reports estimates obtained without the indicator of 2008 investment, which is included in the second column. All outcome equations include year dummies to control for common time-specific shocks. Robust standard errors are clustered at NACE Rev.2 3-digit level to correct for a potential correlation of error terms. Since the EU ETS is one variable of interest and is industry specific, we do not include industry dummies in the regression. The results of the selection equation are shown in Table A2 in the Appendix. In the selection equation, we include variables that are available for all firms (full sample). In addition to year dummies, we also include industry and region dummies as additional restrictions for the identification of the selection equation. Robust standard errors are also clustered at NACE Rev.2 3-digit level. The statistical significance of the Mill's ratios for columns 3 and 4 indicate the presence of selection bias, while these are not statistically significant in other columns. For comparison, we also

[4] We thank an anonymous referee for suggesting this instrumental variable.

Table 1
Determinants of firms' green investment decision.

	Full model (outcome equation)				Probit (selected sample)			
	Pollution control		Cleaner technologies		Pollution control		Cleaner technologies	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Joint08		0.571***		0.805***		0.571***		0.818***
		(0.105)		(0.116)		(0.104)		(0.118)
GVA	0.197***	0.189***	0.131***	0.127**	0.201***	0.193***	0.165***	0.160***
	(0.042)	(0.042)	(0.053)	(0.054)	(0.038)	(0.038)	(0.045)	(0.046)
ETS	−0.014	−0.053	0.15	0.104	−0.013	−0.051	0.159	0.11
	(0.176)	(0.16)	(0.154)	(0.148)	(0.176)	(0.16)	(0.157)	(0.151)
Energy industry	−0.077	−0.039	1.143***	1.165***	−0.08	−0.043	1.105***	1.125***
	(0.321)	(0.318)	(0.177)	(0.169)	(0.318)	(0.314)	(0.176)	(0.169)
Age	0.006	0.005	0.005	0.007	0.006	0.005	0.006	0.007
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)
Age^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Market share	−0.261	−0.245	1.805***	1.812***	−0.27	−0.256	1.766***	1.771***
	(0.596)	(0.598)	(0.625)	(0.596)	(0.607)	(0.612)	(0.639)	(0.609)
HHI	−0.455	−0.365	−1.840***	−1.846***	−0.457	−0.366	−1.846***	−1.843***
	(0.504)	(0.487)	(0.648)	(0.617)	(0.505)	(0.487)	(0.654)	(0.623)
Skills	−0.011	−0.016	0.000	0.044	−0.01	−0.016	0.000	0.044
	(0.142)	(0.143)	(0.17)	(0.18)	(0.142)	(0.143)	(0.172)	(0.182)
Importer	0.250**	0.263**	0.219*	0.244**	0.253**	0.265**	0.239**	0.263**
	(0.118)	(0.123)	(0.113)	(0.116)	(0.12)	(0.125)	(0.112)	(0.116)
Exporter	0.081	0.082	0.134	0.135	0.083	0.084	0.161*	0.159*
	(0.083)	(0.079)	(0.085)	(0.085)	(0.083)	(0.079)	(0.087)	(0.087)
Supply chain link	0.195**	0.207**	0.190**	0.201**	0.195**	0.206**	0.190**	0.202**
	(0.084)	(0.09)	(0.088)	(0.086)	(0.084)	(0.09)	(0.09)	(0.087)
Local	0.373***	0.372***	0.507***	0.511***	0.370***	0.369***	0.477***	0.482***
	(0.118)	(0.119)	(0.111)	(0.115)	(0.119)	(0.12)	(0.109)	(0.113)
Energy intensity	0.205***	0.204***	0.076	0.086	0.204***	0.204***	0.073	0.082
	(0.058)	(0.058)	(0.068)	(0.066)	(0.058)	(0.058)	(0.068)	(0.066)
Intangible	−0.039	−0.043	0.035	0.022	−0.038	−0.041	0.04	0.028
	(0.071)	(0.072)	(0.096)	(0.09)	(0.072)	(0.073)	(0.096)	(0.09)
Tangible	0.053	0.049	0.051	0.039	0.053	0.049	0.06	0.047
	(0.074)	(0.071)	(0.097)	(0.095)	(0.074)	(0.071)	(0.098)	(0.096)
Productivity	−0.137**	−0.130*	−0.091	−0.098	−0.140**	−0.134**	−0.121*	−0.127**
	(0.066)	(0.067)	(0.071)	(0.069)	(0.067)	(0.067)	(0.066)	(0.064)
Constant	−3.307***	−3.288***	−2.839***	−3.090***	−3.335***	−3.319***	−3.132***	−3.369***
	(0.48)	(0.47)	(0.566)	(0.581)	(0.47)	(0.46)	(0.543)	(0.551)
Observations	8151	8151	8151	8151	8151	8151	8151	8151
atanh ρ	−0.026	−0.03	−0.283**	−0.273**				
	(0.124)	(0.125)	(0.128)	(0.133)				
pseudo R^2					0.053	0.064	0.079	0.106
Wald test					142.97***	156.36***	718.78***	1096.71***

Notes: Year dummies are included in the outcome equation. Year, region, and industry dummies are included in the selection equation. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had green investments in 2008. *$p < .1$; **$p < .05$; ***$p < .01$. atanh $\rho = 0.5 \cdot \ln((1+\rho)/(1-\rho))$. The Wald test is for the joint significance of all coefficients in the probit models.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

estimate a probit model on firms that answer Form F (typically with 20 and more persons engaged), removing the selection stage. Regression results are shown in the right panel of Table 1, and which are very similar to those from Heckman models.

In the second set of model specifications, we include detailed information on the country of origin and export destinations. All other variables are the same as the ones used in the previous model mentioned above. In Table 3, we show the estimated coefficients for export destinations and headquarter location. The full set of estimates are shown in Table A3 in the Appendix. The coefficients in the model are very similar to those in the previous models in Table 1.

Our main results are summarized as follows. Estimates obtained with the Heckman selection models suggest that firms that invested in environmental protection in 2008 are more likely to continue to invest in the following years. Evidence of this persistency appears in all models. Larger firms (with a larger gross value added) are more likely to invest in environmental protection. Higher energy intensity appears to have a significant effect on firms' decision to invest in equipment for pollution control but does not have a significant impact on firms' decisions to invest in equipment linked to cleaner technologies. In addition, firms in the energy industry are more likely to invest in equipment linked to cleaner technologies than firms in other industries.

Our results indicate that environmental regulations (EU ETS) have no significant effect on firms' propensity to invest in equipment for pollution control or in equipment linked to cleaner technologies. The estimates shown in columns (3) and (4) in Table 1 indicate that firms in industries with a lower market concentration are more likely to invest in equipment linked to cleaner technologies, suggesting that competition within industry incentivizes firms to invest in cleaner technologies (a closer linkage to green innovation). Further, firms with a higher market share in an industry are more likely to invest in equipment linked to cleaner technologies. On the other hand, market structure does not seem to have significant effects on firms' propensity to invest in equipment for pollution control.

Further, our results suggest that firms with supply chain linkages are more likely to invest in environmental protection. This result indicates that firms belonging to a larger corporate group have a higher probability to engage in environmental protection than other firms, over and

Table 2
Determinants of firms' green investment decision, detailed exporting destination and country of origin.

	Full sample with selection		Probit (selected sample)	
	Pollution control	Cleaner technologies	Pollution control	Cleaner technologies
	(1)	(2)	(3)	(4)
Export destination:				
Ex_uk	0.152**	0.193**	0.152**	0.210**
	(0.077)	(0.08)	(0.076)	(0.082)
Ex_resteu	−0.024	−0.028	−0.024	−0.028
	(0.082)	(0.101)	(0.082)	(0.103)
Ex_usa	−0.287***	−0.127	−0.287***	−0.134
	(0.09)	(0.121)	(0.09)	(0.123)
Ex_row	0.075	0.011	0.075	0.01
	(0.094)	(0.091)	(0.094)	(0.092)
Ex_euro	0.109	−0.042	0.109	−0.037
	(0.084)	(0.086)	(0.085)	(0.086)
HQ location:				
UK	−0.182	−0.964***	−0.182	−0.935***
	(0.215)	(0.351)	(0.213)	(0.351)
Euro zone	−0.406**	−0.413**	−0.406***	−0.375**
	(0.158)	(0.188)	(0.157)	(0.189)
Rest EU	−0.358	−0.197	−0.358	−0.162
	(0.565)	(0.405)	(0.566)	(0.412)
USA	−0.348**	−0.499**	−0.348**	−0.477**
	(0.137)	(0.202)	(0.138)	(0.198)
ROW	−0.347	−0.312*	−0.347	−0.283
	(0.234)	(0.183)	(0.233)	(0.184)

Notes: The full set of results are shown in Table A2 in the Appendix. Robust standard errors are clustered at NACE Rev.2 3-digit level. *p < .1; **p < .05; ***p < .01.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

above other factors. However, firms' decisions to invest in environmental protection are negatively correlated with labour productivity. Further, such decisions do not appear to be influenced by firms' investments in other tangible or intangible assets, and by employees' skills.

As shown in Table 1, importing firms are more likely to invest in equipment for pollution control and in equipment linked to cleaner technologies.[5] This result might reflect the fact that Ireland's imports are predominantly from advanced economies (the UK, the US, France, Germany, the Netherlands, Belgium, and Japan accounted for 71% of the value of imports of goods in 2018) and importers might need to invest in equipment for pollution control and linked to cleaner technology to adapt their production to required technical standards of inputs or goods imported from such countries. It is well documented that imports are a channel of technology diffusion (see for example the review of this evidence by Keller, 2004).

When we break down exports by country of destination, Table 2 suggests that firms that export to the UK are more likely to invest in environmental protection than firms that do not export to UK. This result might reflect higher standards on "green" products in the UK. However, firms that export to the US are less likely to invest in equipment for pollution control relative to firms that do not export to the US. This result could be related to the fact that exports to the US are to a large extent by foreign affiliates of US multinationals which are likely to have advanced technologies, including equipment for pollution control and cleaner technologies. We return to this point below. Exporting to other areas does not have a significant impact on firms' propensity to engage in green investments.

Foreign-owned firms are less likely to invest in environmental protection relative to local (Irish-owned) firms (Table 1). This result is driven mainly by firms with headquarters in the US and the Eurozone (and the UK for investment in equipment linked to cleaner technologies) as shown in Table 2. One possible explanation is that these firms already

Table 3
Industry peer effects.

	Industry peer effects			
	Pollution control		Cleaner technologies	
	Probit	IV probit	Probit	IV probit
	(1)	(2)	(3)	(4)
Peer rate	0.044***	0.103**	−0.001	0.123**
	(0.013)	(0.043)	(0.023)	(0.057)
Joint08	0.564***	0.543***	0.805***	0.781***
	(0.105)	(0.119)	(0.116)	(0.106)
GVA	0.174***	0.151***	0.127**	0.089
	(0.039)	(0.043)	(0.052)	(0.054)
ETS	−0.051	−0.034	0.104	0.075
	(0.141)	(0.136)	(0.148)	(0.142)
Energy industry	−0.021	−0.031	1.175***	0.019
	(0.322)	(0.264)	(0.28)	(0.555)
Age	0.005	0.005	0.007	0.007
	(0.005)	(0.004)	(0.006)	(0.007)
Age^2	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Market share	0.075	0.445	1.802***	2.469***
	(0.569)	(0.72)	(0.575)	(0.738)
HHI	−0.496	−0.591	−1.842***	−1.867***
	(0.516)	(0.554)	(0.591)	(0.578)
Skills	0.017	0.068	0.043	0.135
	(0.138)	(0.151)	(0.182)	(0.175)
Importer	0.267**	0.263**	0.244**	0.243*
	(0.12)	(0.126)	(0.116)	(0.131)
Exporter	0.071	0.053	0.135	0.118
	(0.078)	(0.083)	(0.085)	(0.096)
Supply chain link	0.205**	0.199**	0.202**	0.181*
	(0.09)	(0.091)	(0.085)	(0.097)
Local	0.351***	0.310**	0.512***	0.411***
	(0.116)	(0.142)	(0.114)	(0.138)
Energy intensity	0.178***	0.136*	0.087	0.008
	(0.054)	(0.071)	(0.063)	(0.09)
Intangible	−0.036	−0.027	0.022	0.025
	(0.072)	(0.081)	(0.09)	(0.113)
Tangible	0.048	0.047	0.039	0.043
	(0.071)	(0.084)	(0.095)	(0.121)
Productivity	−0.130**	−0.126**	−0.098	−0.101
	(0.065)	(0.061)	(0.068)	(0.071)
Mill's ratio	−0.014	0.002	−0.273**	−0.245
	(0.123)	(0.118)	(0.132)	(0.346)
Constant	−3.374***	−3.471***	−3.088***	−3.256***
	(0.445)	(0.44)	(0.584)	(0.541)
Observations	16,199	16,199	16,199	16,199
atanh ρ		−0.130		−0.232**
		(0.094)		(0.108)
$ln(\sigma)$		0.652***		0.486***
		(0.057)		(0.064)
Wald: Joint		250.06***		793.69***
Wald: Exogeneity		2.101		5.322**
F-test for IVs (first stage)		106.77***		58.07***

Notes: All models are estimated with a two-step Heckman selection estimator. The results for the selection equation are not shown but are available upon request from the authors. Year, region, and industry dummies are included in the selection equation. Year dummies are included in the outcome equation. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had green investments in 2008. *p < .1; **p < .05; ***p < .01. The Wald test reports the χ^2 statistic for the joint significance of the IV models' coefficients. The Wald test of exogeneity reports the χ^2 statistics. The null hypothesis is that the instrumented variable (peer rate) is exogenous. For a given firm *i*, the IV for the industry peer effect is the proportion of local firms in the peer group in the same industry with a firm *i*.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

[5] Our results are not directly comparable to Haller and Murphy (2012) because they do not control for importers in their model specification.

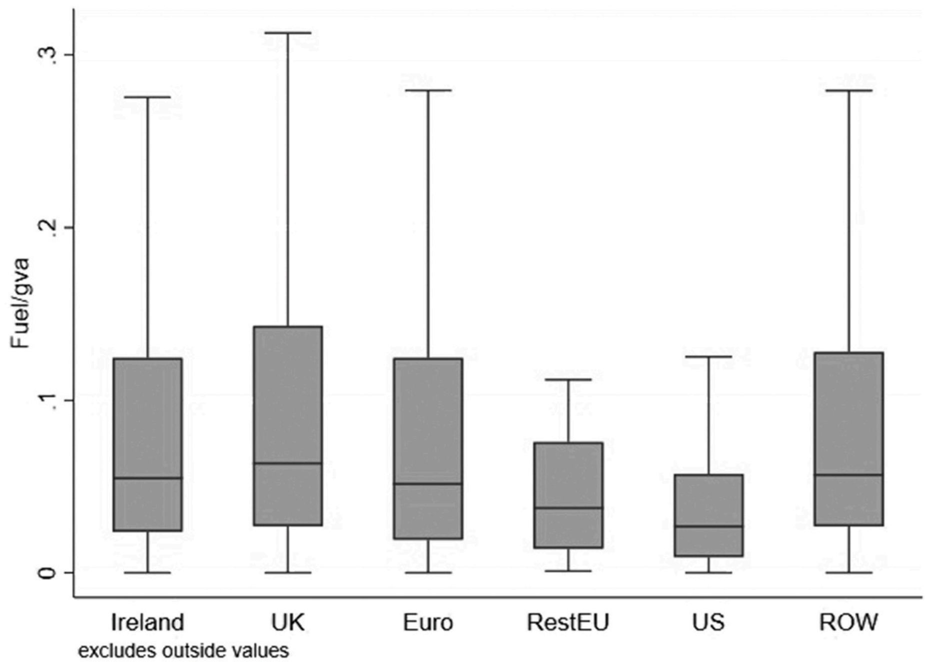

Fig. 4. Energy intensity for local firms and foreign affiliates by country of origin. Notes: The box plot shows the mean, 75th percentile, 25th percentile and the upper and lower adjacent values. *Source*: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

had equipment for environmental protection and cleaner technologies, and thus, there is no need for further investment. To test this hypothesis, we examine whether firms that are foreign affiliates tend to use energy more efficiently (or simply, because they use less energy over the output unit). Fig. 4 provides the box plots of energy intensity by firms' country of ownership, showing the mean, the 75th percentile, 25th percentile and the upper and lower adjacent values. This figure suggests that for each output unit, firms with headquarters in the US tend to use less energy than that of local firms. However, the energy intensity of firms with headquarters in the Eurozone seems to be not significantly different from that of Irish-owned firms. These results are consistent with previous evidence from Ireland (Haller and Murphy, 2012) and other countries showing that foreign affiliates have more energy efficient technologies and they are less likely than local firms to invest in environmental protection (Aden and Kyu-Hong, 1999 for South Korea; Collins and Harris, 2005 for the United Kingdom).

4.2. Spillover effects

As discussed above, decisions of firms with green investments may affect a firm's decision to invest in environmental protection, as a firm may learn from the decisions of peer firms. Since the peer effect variable is likely to be endogenous, we use the average of peer firm characteristics as instrumental variables. Tables 3 and 4 present the estimates of peer firm effects on firms' investment in environmental protection. Table 3 presents the set of results corresponding to peer effects in the same industry. Table 4 shows the estimated peer effects when peer firms in the same NUTS 3 region are considered. For each dependent variable, the results from the standard probit regression with Heckman selection are shown in the first column and the results of the IV probit model with Heckman selection are shown in the second column. The results from the first stage regressions are shown in Table A4 in the Appendix.

The main explanatory variable of interest in these tables is the peer rate (the investment rate of peer firms in the same industry or region). The results shown in Table 3 indicate that firms' decision to invest in equipment for pollution control and in equipment linked to cleaner technologies are positively affected by other firms' decision in the same industry. In the case of investment in equipment for pollution control, the estimates obtained with the standard probit model are not biased by reverse causality since the Wald test does not reject the exogeneity of the peer rate. However, the exogeneity of the peer rate is rejected in the case of investment in equipment linked to cleaner technologies. In this later case, the standard probit model underestimates the true effect of peer rate on the propensity of firms to invest in equipment for cleaner technologies. After correcting for endogenity, the estimates obtained with the IV probit model indicate significant positive spillover effects from green investors in the same industry on firms' propensity to invest in equipment linked to cleaner technologies. The F-statistics for the significance of the instrumental variable (the proportion of local firms in the same industry) is large and highly significant.

The results shown in Table 4 suggest that firms also learn from other firms in the same region, as they are close to each other geographically. The Wald test for the exogeneity of peer rate indicates that this variable is endogenous to the propensity of firms to invest in green investments. After correcting for this endogenity, the estimates for peer rate are positive and significant in the case of both types of green investments indicating the presence of spillovers from green investors in the same region on the propensity of firms to engage in green investments. The F-statistics for the joint significance of the instrumental variables (the proportion of local firms in the same region, the proportion of exporters in the same region, the average energy intensity of firms in the same region) are large and highly significant. The identification strategy is valid as the over-identifying instruments are all exogenous.

Comparing the magnitude of the coefficients associated with the peer rate, we find that a firm's decision to invest in environmental protection is influenced to a larger extent by firms with green investments in the same region than by other green investors in the same industry. This finding adds new evidence to the literature of geographically localized knowledge spillovers provided by Jaffe et al. (1993) and Keller (2002).

Taken together, these findings suggest that peer firms' investments in environmental protection (within the same industry or within the same region) could increase a firm's awareness and engagement in green investments, as firms learn from each other.

Table 4
Spatial peer effects.

	Spatial peer effects			
	Pollution control		Cleaner technologies	
	Probit	IV probit	Probit	IV probit
	(5)	(6)	(7)	(8)
Peer rate	−0.038	0.196***	−0.009	0.242**
	(0.043)	(0.07)	(0.032)	(0.108)
Joint08	0.569***	0.570***	0.806***	0.791***
	(0.104)	(0.105)	(0.116)	(0.122)
GVA	0.191***	0.180***	0.127**	0.129**
	(0.041)	(0.045)	(0.051)	(0.055)
ETS	−0.053	−0.055	0.104	0.102
	(0.16)	(0.179)	(0.148)	(0.167)
Energy industry	−0.047	0.014	1.166***	1.121***
	(0.316)	(0.266)	(0.169)	(0.206)
Age	0.005	0.004	0.007	0.007
	(0.005)	(0.006)	(0.006)	(0.007)
Age^2	0.000	0.000	0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Market share	−0.263	−0.172	1.814***	1.781***
	(0.598)	(0.664)	(0.594)	(0.681)
HHI	−0.359	−0.369	−1.848***	−1.788**
	(0.485)	(0.643)	(0.616)	(0.714)
Skills	−0.016	−0.01	0.043	0.041
	(0.143)	(0.154)	(0.181)	(0.181)
Importer	0.263**	0.258*	0.243**	0.261**
	(0.123)	(0.136)	(0.117)	(0.122)
Exporter	0.081	0.08	0.135	0.124
	(0.079)	(0.084)	(0.085)	(0.095)
Supply chain link	0.206**	0.195*	0.202**	0.200**
	(0.09)	(0.103)	(0.086)	(0.089)
Local	0.375***	0.337**	0.511***	0.478***
	(0.119)	(0.131)	(0.115)	(0.119)
Energy intensity	0.207***	0.194***	0.087	0.078
	(0.057)	(0.07)	(0.066)	(0.08)
Intangible	−0.045	−0.038	0.022	0.026
	(0.072)	(0.082)	(0.09)	(0.116)
Tangible	0.048	0.051	0.039	0.045
	(0.07)	(0.081)	(0.095)	(0.121)
Productivity	−0.132**	−0.121*	−0.098	−0.098
	(0.066)	(0.068)	(0.069)	(0.071)
Mill's ratio	−0.031	−0.032	−0.274**	−0.264
	(0.125)	(0.128)	(0.133)	(0.22)
Constant	−3.225***	−3.563***	−3.070***	−3.439***
	(0.476)	(0.522)	(0.593)	(0.587)
Observations	16,199	16199	16,199	16199
atanh ρ		−0.213***		−0.231**
		(0.066)		(0.103)
$ln(\sigma)$		−0.254***		−0.190***
		(0.007)		(0.020)
Wald: Joint		146.54***		796.949***
Wald: Exogeneity		10.010***		5.035**
F-test for IVs (first stage)		275.41***		138.96***
Over-id: (p-values)		0.929		0.970

Notes: All models are estimated with a two-step Heckman selection. The results for the selection equation are not shown but are available upon request from the authors. Year, region, and industry dummies are included in the selection equation. Year dummies are included in the outcome equation. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had green investments in 2008. *$p < .1$; **$p < .05$; ***$p < .01$. The Wald test reports the χ^2statistic for the joint significance of the IV models' coefficients. The Wald test of exogeneity reports the χ^2 statistics. The null hypothesis is that the instrumented variable (peer rate) is exogenous. The IVs for spatial peer effects of pollution control are the proportion of local firms (peer_r_local), the proportion of exporters (peer_r_exporter), and the average energy intensity of firms (peer_r_fuel) in the same region. The IVs for spatial peer effects in the case of investment in equipment linked to cleaner technologies are the proportion of local firms (peer_r_local), the proportion of importers (peer_r_importer), and the average energy intensity of firms (peer_r_fuel) in the same region. The test for overidentification is the refutability (mREF) test proposed by Guevara (2018). The null hypothesis is that all the instruments are exogenous.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

4.3. Discussion

Duflo and Daez (2002), and Manski (1993, 1995) argue that the correlation of behaviours within a peer group may not necessarily be driven by peer effects (the action of peer firms). First, firms in the same group may have similar preferences which are unobserved by researchers. For example, firms in the same region behave alike because they are subject to the same local environmental regulations and the same local authorities. Second, a firm's decision may vary with the average characteristics of the group (but not the average behaviours). They refer to this effect as "exogenous social effect" (or contextual effect). For example, a firm's investment decision might be correlated with the average energy intensity of an industry, as all firms in that industry might have a higher intensity than firms in other industries. Only when both effects are controlled for, we can then identify the peer effects (endogenous social effects).

The correlation effect is easier to control for when instruments that are exogenous to the system are used. As discussed earlier, these instruments include average characteristics of peers, as they are unlikely to be affected by firms' actions. However, we have not yet addressed the problem of exogenous social effects. An exogenous social effect becomes problematic when using average characteristics of peers as instruments to identify an endogenous social effect, as these instruments may directly affect the outcome but not through instrumented peer rates. Exogenous social effects in general cannot be ruled out, even after controlling for firms' own characteristics (Duflo and Daez, 2002). However, in our case, we argue that an exogenous social effect is unlikely to bias the estimates, as the main instrument in our model is the proportion of Irish-owned firms in an industry (or region). Indeed, some industries might have a higher proportion of local firms than other industries. However, a firm is unlikely to invest in environmental protection only because it has more Irish-owned firms as its peers (exogenous social effect). It is more likely that this firm's action is affected by the actions of other Irish firms nearby (in the same industry or region). Therefore, we are confident that our results are not affected by a potential presence of an exogenous social effect.

Furthermore, if firms in a peer group are heterogenous, one may look at the peer effects within the same subgroups and across subgroups as suggested by Duflo and Daez (2002). If peer effects are present, they would be stronger in the former. One caveat in our paper is that, defining subgroups is difficult as the investment rate is very low, so there might be not enough variation across firms for identification purposes. However, this is an interesting question for future research.

5. Conclusions

This paper examines factors underlying firms' propensity to engage in green investments. We use an IV-probit model with sample selection estimated with micro data from Ireland's industry sector over the period 2008–2016 to analyse internal factors such as firm characteristics and factors external to the firm including environmental regulations, competition and spillovers from other firms with green investments in the same industry or in the same region.

Our results indicate that large firms, importers, and firms which are part of an enterprise group are more likely to invest in equipment for pollution control and in equipment linked to cleaner technologies. Foreign-owned firms are less likely than local firms to invest in environmental protection, particularly foreign affiliates of companies with headquarters based in the US or in the Euro zone. This result might reflect the fact that these foreign affiliates already have adequate equipment for air pollution control and cleaner technologies and there is no need for further investment. Our results indicate that this might be indeed the case for foreign affiliates of US based multinationals. Comparing the energy intensity for local firms and foreign affiliates, we find that firms with headquarters in the US tend to use less energy per unit of output than local firms. This result is consistent with evidence from other countries suggesting that foreign affiliates employ more energy efficient technologies and are therefore less likely than local firms to invest in environmental protection (Aden and Kyu-Hong, 1999 for South Korea; Collins and Harris, 2005 for the United Kingdom). Further, our results indicate that the energy intensity of firms' production is positively linked to their propensity to invest in equipment for pollution control but not to invest in cleaner technologies.

Within industry competition measured as market share and market concentration is an important driver of firms' investment in equipment linked to cleaner technologies. In contrast, environmental regulations do not appear to have a significant impact on firms' propensity to engage in green investments. This insignificant impact might reflect aggregation bias given that we use measures of industry rather than firm-level exposure to environmental regulations.

Finally, our results uncover significant positive spillover effects from firms with investment in environmental protection in the same industry or the same region on firms' propensity to invest in environmental protection.

To the extent that incentivizing more firms to invest in environmental protection could contribute to improved environmental quality and a faster transition to a more sustainable long-term growth, our results suggest that there could be a need for targeted policy measures to enable in particular small and medium-sized firms to invest in environmental protection. Our findings also suggest that promoting competition could boost firms' investments in green technologies while facilitating learning from existing green investors within the same industry and within the same region could further foster firms' investments in environmental protection.

CRediT authorship contribution statement

Iulia Siedschlag: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Weijie Yan:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2021.127554.

Appendix

Table A1
Definition of variables and summary statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
Form F firms (firm-year observations: 8151)					
PC	Investment in equipment for pollution control (1000 euro)	15.19	249.68	0.00	10561.87
CT	Investment in equipment linked to cleaner technologies (1000 euro)	138.49	3735.92	0.00	173255.30
PC_d	Dummy = 1 if firm invests in pollution control	0.04	0.19	0	1
CT_d	Dummy = 1 if firm invests in cleaner technologies	0.04	0.19	0	1
ETS	Dummy = 1 if firm is in a sector under EU ETS (NACE Rev.2. codes: 17, 19, 20, 23, 24)	0.15	0.36	0	1
Energy industry	Dummy = 1 if firm is in NACE Rev.2.code:35	0.008	0.087	0	1
GVA	Log of gross value added (1000 euro)	8.10	2.03	0.69	15.66
Productivity	Log of GVA per head (1000 euro)	4.04	1.13	0.00	7.81
Age	Age of a firm (relative to birth year 2008)	30.63	15.86	1	135
Age^2	Age of a firm squared	1189.82	1454.27	1	18225
Market share	Firm's industry share (within NACE Rev.2. industry)	0.10	0.10	0.01	1.00
HHI	HHI index of an industry (within NACE Rev.2. 2 digit industry)	3.76	0.40	0.00	4.96
Skills	Labour cost per person engaged (1000 euro)	0.24	0.84	0.00	6.61
Energy intensity	Log of fuel consumption over GVA. 1 is added to the ratio before taking the variable in log.	0.16	0.64	0.00	6.79
Intangible	Log of investment in intangible assets over GVA. 1 is added to the ratio before taking the variable in log.	0.12	0.55	0.00	5.80
Tangible	Log of investment in tangible assets over GVA. 1 is added to the ratio before taking the variable in log.	0.10	0.10	0.01	1.00
Local	Dummy = 1 if firm is Irish owned	0.32	0.47	0	1
Supply chain link	Dummy = 1 if firm transfers intermediate material to affiliates	0.25	0.43	0	1
Importer	Dummy = 1 if firm is an importer	0.84	0.37	0	1
Exporter	Dummy = 1 if firm is an exporter	0.73	0.44	0	1
Ex_uk	Dummy = 1 if firm exports to UK	0.56	0.50	0	1
Ex_euro	Dummy, = 1 if it exports to euro zone	0.48	0.50	0	1
Ex_resteu	Dummy = 1 if firm exports to the rest EU	0.20	0.40	0	1
Ex_usa	Dummy = 1 if firm exports to the USA	0.26	0.44	0	1
Ex_row	Dummy = 1 if firm exports to rest of the world	0.31	0.46	0	1
Firms with capital/current expenditures on environmental production in 2008 (number of firms in 2008: 1144)					
Joint08 (PC)	Dummy = 1 if firm has invested in PC in 2008	0.04	0.20	0	1
Joint08 (CT)	Dummy, = 1 if firm it has invested in CT in 2008	0.03	0.18	0	1
Peer participation rates and characteristics (firm-year observations: 8151)					
peer_s_PC	Proportion of firms that invest in pollution control in the same industry (NACE Rev.2. 2 digit) other than a given firm (*100)	2.30	2.15	0.00	33.33
peer_r_PC	Proportion of firms that invest in pollution control in the same region other than a given firm (*100)	1.98	0.88	0.00	4.14
peer_s_CT	Proportion of firms that invest in clean technology in the same industry (NACE Rev.2. 2 digit) other than a given firm (*100)	2.16	1.99	0.00	33.33
peer_r_CT	Proportion of firms that invest in clean technology in the same region other than a given firm (*100)	1.92	0.93	0.00	5.51
peer_s_exporter	Proportion of firms that are exporters in the same industry (NACE Rev.2. 2 digit) other than a given firm	0.42	0.18	0.00	1.00
peer_r_exporter	Proportion of firms that are exporter in the same region other than a given firm	0.37	0.07	0.25	0.53
peer_s_local	Proportion of firms that are Irish in the same industry (NACE Rev.2. 2 digit) other than a given firm	0.18	0.21	0.00	1.00
peer_r_local	Proportion of firms that are Irish owned in the same region other than a given firm	0.17	0.19	0.00	0.46
peer_s_fuel	Peers' average of energy intensity for the same industry, log of fuel consumption over GVA.	0.13	0.10	0.00	1.41
peer_r_fuel	Peers' average of energy intensity in the same region, log of fuel consumption over GVA.	0.12	0.04	0.03	0.25
Full sample (firm-year observations: 16,199)					
GVA	Log of gross value added (1000 euro)	6.91	2.10	0.69	15.66
Emp20	Dummy = 1 if total persons engaged is 20 or more	0.50	0.50	0	1
Capital	Log of total investment in capital assets (1000 euro)	3.49	2.97	0.00	14.81
Local	Dummy = 1 if firm is Irish owned	0.36	0.48	0	1

Source: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

Table A2
Determinants of firms' probability to respond to Form F (selection equation)

	Pollution control		Cleaner technologies	
	(1)	(2)	(3)	(4)
GVA	0.129***	0.129***	0.129***	0.129***
	(0.018)	(0.018)	(0.018)	(0.018)
Emp20	2.399***	2.399***	2.394***	2.394***
	(0.059)	(0.059)	(0.059)	(0.059)
Capital	0.079***	0.079***	0.080***	0.080***
	(0.023)	(0.023)	(0.023)	(0.023)
Local	−0.684***	−0.684***	−0.686***	−0.686***
	(0.099)	(0.099)	(0.100)	(0.100)
Constant	−2.238***	−2.238***	−2.234***	−2.235***

(*continued on next page*)

Table A2 (*continued*)

	Pollution control		Cleaner technologies	
	(1)	(2)	(3)	(4)
	(0.117)	(0.117)	(0.117)	(0.117)
Observations	16,199	16,199	16,199	16,199
Wald test $\rho = 0$	0.046	0.057	4.866**	4.228**
Log-likelihood	−5.40E+03	−5.30E+03	−5.30E+03	−5.30E+03

Notes: Year dummies are included in the outcome equation. Year, region, and industry dummies are included in the selection equation. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had green investments in 2008. *p < .1; **p < .05; ***p < .01.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

Table A3
Determinants of firms' probability to invest in environmental protection, detailed exporting destination and location of parent firms headquarter.

	Full sample with selection		Probit (selected sample)	
	Pollution control	Cleaner technologies	Pollution control	Cleaner technologies
	(1)	(2)	(3)	(4)
Joint08	0.577***	0.812***	0.577***	0.824***
	(0.111)	(0.115)	(0.11)	(0.117)
GVA	0.197***	0.141***	0.197***	0.174***
	(0.041)	(0.054)	(0.036)	(0.047)
ETS	−0.052	0.084	−0.052	0.088
	(0.159)	(0.15)	(0.159)	(0.153)
Energy industry	−0.119	1.019***	−0.119	0.973***
	(0.321)	(0.155)	(0.317)	(0.153)
Age	0.004	0.006	0.004	0.006
	(0.004)	(0.006)	(0.004)	(0.006)
Age2	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Market share	−0.314	1.721***	−0.313	1.673***
	(0.547)	(0.57)	(0.561)	(0.583)
HHI	−0.29	−1.699***	−0.29	−1.689***
	(0.459)	(0.59)	(0.458)	(0.596)
Skills	0.027	0.063	0.027	0.064
	(0.128)	(0.17)	(0.129)	(0.171)
Importer	0.248**	0.258**	0.247**	0.281**
	(0.114)	(0.12)	(0.116)	(0.119)
Supply chain link	0.208**	0.215***	0.208**	0.215***
	(0.082)	(0.081)	(0.082)	(0.082)
Energy intensity	0.193***	0.079	0.193***	0.075
	(0.057)	(0.065)	(0.057)	(0.065)
Intangible	−0.020	0.050	−0.02	0.058
	(0.073)	(0.098)	(0.074)	(0.098)
Tangible	0.048	0.045	0.048	0.053
	(0.071)	(0.096)	(0.071)	(0.097)
Productivity	−0.135**	−0.100	−0.135**	−0.128**
	(0.066)	(0.071)	(0.066)	(0.065)
Constant	−3.177***	−2.945***	−3.174***	−3.253***
	(0.462)	(0.531)	(0.438)	(0.504)
Export destination:				
Ex_uk	0.152**	0.193**	0.152**	0.210**
	(0.077)	(0.08)	(0.076)	(0.082)
Ex_resteu	−0.024	−0.028	−0.024	−0.028
	(0.082)	(0.101)	(0.082)	(0.103)
Ex_usa	−0.287***	−0.127	−0.287***	−0.134
	(0.09)	(0.121)	(0.09)	(0.123)
Ex_row	0.075	0.011	0.075	0.01
	(0.094)	(0.091)	(0.094)	(0.092)
Ex_euro	0.109	−0.042	0.109	−0.037
	(0.084)	(0.086)	(0.085)	(0.086)
HQ location:				
UK	−0.182	−0.964***	−0.182	−0.935***
	(0.215)	(0.351)	(0.213)	(0.351)
Euro zone	−0.406**	−0.413**	−0.406***	−0.375**
	(0.158)	(0.188)	(0.157)	(0.189)
Rest EU	−0.358	−0.197	−0.358	−0.162
	(0.565)	(0.405)	(0.566)	(0.412)
USA	−0.348**	−0.499**	−0.348**	−0.477**
	(0.137)	(0.202)	(0.138)	(0.198)
ROW	−0.347	−0.312*	−0.347	−0.283
	(0.234)	(0.183)	(0.233)	(0.184)

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Table A3 (*continued*)

	Full sample with selection		Probit (selected sample)	
	Pollution control	Cleaner technologies	Pollution control	Cleaner technologies
	(1)	(2)	(3)	(4)
Selection equation:				
GVA	0.129***	0.129***		
	(0.018)	(0.018)		
Emp20	2.400***	2.395***		
	(0.059)	(0.059)		
Capital	0.078***	0.080***		
	(0.023)	(0.023)		
Local	−0.684***	−0.685***		
	(0.099)	(0.1)		
Constant	−2.239***	−2.235***		
	(0.117)	(0.117)		
Observations	16,199	16,199	8151	8151
atanh ρ	0.003	−0.265**		
	(0.131)	(0.131)		
pseudo R^2			0.073	0.11
Wald test: χ^2			197.7***	1225.5***

Notes: Year dummies are included in the outcome equation. Year, region, and industry dummies are included in the selection equation. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had green investment in 2008. *p < .1; **p < .05; ***p < .01. atanh.$\rho = 0.5 \cdot ln((1+\rho)/(1-\rho))$.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

Table A4
Peer effects, first stage results of IV probit models (outcome equation)

	Industry peer effects		Spatial peer effects			
	pollution control	clean tech	pollution control		clean tech	
	(1)	(2)	(3)	(4)	(5)	(6)
peer_s_local/peer_r_local	7.809***	6.204***	10.990***	15.447***	7.259***	2.934***
	(0.766)	(0.825)	(0.727)	(0.658)	(0.441)	(0.682)
Peer_r_importer			−3.933***		−5.924***	
			(0.864)		(0.367)	
peer_r_exporter				−6.073***		−0.179
				(0.492)		(0.361)
peer_r_fuel			2.925***	3.388***	6.045***	5.576***
			(0.321)	(0.299)	(0.446)	(0.561)
Joint08	0.269	0.088	−0.063	−0.043	0.016	0.029
	(0.178)	(0.108)	(0.045)	(0.044)	(0.065)	(0.071)
GVA	0.299***	0.268***	0.023*	0.025**	−0.011	−0.009
	(0.060)	(0.076)	(0.013)	(0.012)	(0.011)	(0.016)
ETS	−0.097	0.344	0.011	0.021	0.015	0.009
	(0.486)	(0.35)	(0.03)	(0.032)	(0.035)	(0.034)
Energy industry	0.159	9.001***	−0.215***	−0.221***	0.083	0.066
	(0.365)	(0.495)	(0.042)	(0.052)	(0.102)	(0.122)
Age	−0.001	−0.002	0.001	0.001	−0.002	−0.002
	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)
Age^2	0.000	0.000	−0.000	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Market share	−5.980***	−5.787***	−0.376*	−0.330	0.059	0.048
	(1.237)	(1.457)	(0.228)	(0.204)	(0.17)	(0.205)
HHI	3.168***	1.581	0.098	0.058	−0.075	−0.113
	(1.190)	(1.212)	(0.178)	(0.162)	(0.125)	(0.141)
Skills	−0.475*	−0.378**	0.036	−0.020	−0.02	0.027
	(0.246)	(0.158)	(0.026)	(0.027)	(0.031)	(0.033)
Importer	0.114	0.087	0.006	0.013	−0.079**	−0.078**
	(0.142)	(0.104)	(0.027)	(0.024)	(0.031)	(0.035)
Exporter	0.228*	0.097	−0.059*	−0.032	0.037	0.019
	(0.124)	(0.078)	(0.034)	(0.03)	(0.026)	(0.029)
Supply chain link	−0.020	0.056	0.039	0.039	−0.004	−0.003
	(0.082)	(0.086)	(0.029)	(0.032)	(0.026)	(0.027)
Local	−0.047	0.192	0.088*	0.093**	0.027	0.034
	(0.140)	(0.143)	(0.05)	(0.041)	(0.032)	(0.031)
Energy intensity	0.455***	0.426***	0.034*	0.039*	0.023	0.021
	(0.096)	(0.08)	(0.019)	(0.021)	(0.019)	(0.02)
Intangible	−0.048	0.097	−0.026	−0.030	−0.015	−0.019
	(0.070)	(0.105)	(0.018)	(0.02)	(0.015)	(0.017)
Tangible	0.041	−0.029	−0.02	−0.023	−0.022	−0.010
	(0.083)	(0.064)	(0.02)	(0.022)	(0.024)	(0.024)
Productivity	−0.016	0.033	−0.039**	−0.041**	0.001	−0.001

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Table A4 (*continued*)

	Industry peer effects		Spatial peer effects			
	pollution control	clean tech	pollution control		clean tech	
	(1)	(2)	(3)	(4)	(5)	(6)
	(0.084)	(0.072)	(0.016)	(0.018)	(0.016)	(0.019)
Mill's ratio	−0.099	−0.024	0.02	0.019	−0.017	−0.018
	(0.103)	(0.082)	(0.022)	(0.022)	(0.022)	(0.027)
Constant	1.033	0.415	2.653***	3.215***	3.056***	0.748***
	(1.016)	(0.677)	(0.339)	(0.177)	(0.193)	(0.16)
Observations	16,199	16,199	16,199	16,199	16,199	16,199
F stat for IVs	106.77***	58.07***	233.41***	275.41***	138.96***	108.35***
F stat for all coefficients	34.33***	96.18***	651.09***	617.82***	179.0***	164.18***
Over-id (p values)			0.964	0.929	0.970	0.860

Notes: All models are estimated with a two-step Heckman selection estimator. The results from the selection equation are not shown but are available from the authors upon request. Year, region, and industry dummies are included in the selection equation. Year dummies are included in the outcome equation. Robust standard errors clustered at NACE Rev.2 3-digit level are shown in parentheses. Joint08 indicates if firm had green investment in 2008. *p < .1; **p < .05; ***p < .01. F stat is the F statistics for the joint significance of the IV's coefficients. The test for over-identification is the refutability test proposed by Guevara (2018). The null hypothesis is that all the instruments are exogenous.
Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

References

Aden, J., Kyu-Hong, A., 1999. What is driving the pollution abatement expenditure behaviour of manufacturing plants in Korea? World Dev. 27 (7), 1203–1214.
Aghion, P., Griffith, R., 2005. Competition and Growth. Zeuthen Lectures, MIT Press.
Aghion, P., Harris, C., Howitt, P., Vickers, J., 2001. Competition, imitation and growth with step-by-step innovation. Rev. Econ. Stud. 68 (3), 467–492.
Anderson, B., Convery, F., Di Maria, C., 2011. Technological change and the EU ETS: the case of Ireland. IEFE Working. Paper No. 43.
Audretsch, D.B., Feldman, M., 1996. R&D and the geography of innovation and production. Am. Econ. Rev. 86, 630–640.
Baptista, R., 2000. Do innovations diffuse faster within geographical clusters? Int. J. Ind. Organ. 18, 515–535.
Battisti, G., Stoneman, P., 2003. Inter-firm and intra-firm effects in the diffusion of new process technologies. Res. Pol. 32, 1641–1655.
Battisti, G., Hollenstein, H., Stoneman, P., Woerter, M., 2007. Inter- and intra-firm diffusion of ICT in the United Kingdom (UK) and Switzerland (CH). An internationally comparative study based on firm-level data. Econ. Innovat. N. Technol. 16, 669–687.
Borghesi, S., Cainelli, G., Mazzanti, M., 2015. Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry. Res. Pol. 44 (3), 669–683.
Cagno, E., Worrell, E., Trianni, A., Pugliese, G., 2013. A novel approach for barriers to industrial energy efficiency. Renew. Sustain. Energy Rev. 19, 290–308.
Case, A., Katz, L., 1991. The Company You Keep: the Effects of Family and Neighborhood on Disadvantaged Youths. Harvard Institute of Economic Research Working Papers, Harvard.
Central Statistics Office, 2016. Standard Report on Methods and Quality on Census of Industrial Production (CIP). Central Statistics Office, Cork. https://www.cso.ie/en/media/csoie/methods/censusofindustrialproductionenterprises/Standard_Report_on_Methods_and_Quality_for_Census_of_Industrial_Production_2016.pdf. (Accessed 29 June 2019).
Collins, A., Harris, R.I., 2005. The impact of foreign ownership and efficiency on pollution abatement expenditure by chemical plants: some UK evidence. Scot. J. Polit. Econ. 52 (5), 747–768.
De Haas, R., Martin, R., Muûls, M., Schweiger, H., 2020. Banking on the environment? Financial frictions, firm management, and green investments. Available at: SSRN: https://ssrn.com/abstract=3703699 https://doi.org/10.2139/ssrn.3703699.
Dechezleprêtre, A., Nachtigall, D., Venmans, F., 2018. The joint impact of the European Union emissions trading system on carbon emissions and economic performance. OECD Working. Paper ECP/WKP 2018/63.
Duflo, E., Saez, E., 2002. Participation and investment decisions in a retirement plan: the influence of colleagues' choices. J. *Publ. Econ.* 85 (1), 121–148.
Guevara, C.A., 2018. Overidentification tests for the exogeneity of instruments in discrete choice models. Transp. Res. Part B Methodol. 114, 241–253.
Haller, S.A., Siedschlag, I., 2011. Determinants of ICT adoption: evidence from firm-level data. Appl. Econ. 43, 3775–3788.
Haller, S.A., Murphy, L., 2012. Corporate expenditure on environmental protection. Environ. Resour. Econ. 51 (2), 277–296.
Hrovatin, N., Dolšak, N., Zorić, J., 2016. Factors impacting investments in energy efficiency and clean technologies: empirical evidence from Slovenian manufacturing firms. J. Clean. Prod. 127 (7), 475–486.
Iraldo, F., Testa, F., Frey, M., 2009. Is an environmental management system able to influence environmental and competitive performance? The case of the ecomanagement and audit scheme (EMAS) in the European Union. J. Clean. Prod. 17, 1444–1452.
Jaffe, A., Trajtenberg, M., Henderson, R., 1993. Geographical localization of knowledge spillovers as evidenced by patent citations. Q. J. Econ. 108, 577–598.
Jaraite, J., Di Maria, C., 2016. Did the EU ETS make a difference? An empirical assessment using Lithuanian firm-level data. Energy J. 37 (1), 1–23.
Keller, W., 2002. Geographical localisation of international technology diffusion. Am. Econ. Rev. 92, 120–142.
Keller, W., 2004. International technology diffusion. J. Econ. Lit. 42 (3), 752–782.
Kemp, R., Volpi, M., 2008. The diffusion of clean technologies: a review with suggestions for future diffusion analysis. J. Clean. Prod. 16 (1), S14–S21.
Leary, M., Roberts, M., 2014. Do peer firms affect corporate financial policy? J. Finance 69 (1), 139–178.
López-Gamero, M.D., Molina-Azorín, J.F., Claver-Cortés, E., 2010. The potential of environmental regulation to change managerial perception, environmental management, competitiveness and financial performance. J. Clean. Prod. 18, 963–974.
Mansfield, E., 1963. The speed of response of firms to new techniques. Q. J. Econ. 77, 290–309.
Manski, C., 1993. Identification of endogenous social effects: the reflection problem. Rev. Econ. Stud. 60 (3), 531–542.
Manski, C., 1995. Identification Problems in the Social Sciences. Harvard University Press, Cambridge, MA.
McInerney, C., O'Connor, E., Power, B., Deane, P., McDermott, T., 2019. EU ETS and Competitiveness of Irish Industry. In: 2016-CCRP-MS, vol. 35. EPA Research Report, Dublin.
Molina-Azorín, J.F., Claver-Cortés, E., Pereira-Moliner, J., Tarí, J.J., 2009. Environmental practices and firm performance: an empirical analysis in the Spanish hotel industry. J. Clean. Prod. 17, 516–524.
Montalvo Corral, C., 2003. Sustainable production and consumption systems-cooperation for change: assessing and simulating the willingness of the firm to adopt/develop cleaner technologies. The case of the In-Bond industry in northern Mexico. J. Clean. Prod. 11, 411–426.
Montalvo Corral, C., 2008. General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990-2007. J. Clean. Prod. 16, S7–S13.
Munshi, K., 2004. Social learning in a heterogeneous population: technology diffusion in the Indian Green Revolution. J. Dev. Econ. 73 (1), 185–213. https://doi.org/10.1016/j.jdeveco.2003.03.003.
Murovec, N., Erker, R.S., Prodan, I., 2012. Determinants of environmental investments: testing the structural model. J. Clean. Prod. 37, 265–277.
Porter, M.E., van der Linde, C., 1995. Green and competitive: ending the stalemate. Harv. Bus. Rev. 73, 120–134.
Stoneman, P., 2002. The Economics of Technological Diffusion. Blackwell, Oxford.
Wooldridge, J.M., 2010. Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge, MA.
Xin-gang, Z., Yuan-feng, Z., Yan-bin, L., 2019. The spillovers of foreign direct investment and the convergence of energy intensity. J. Clean. Prod. 206, 611–621.
Zhou, Y., Jiang, J., Ye, B., Hou, B., 2019. Green spillovers of outward foreign direct investment on home countries: evidence from China's province-level data. J. Clean. Prod. 215, 829–844.