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What drives firms’ decisions to spend on environmental protection?

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What Drives Firms' Decisions to Spend on Environmental Protection?[1]

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Abstract

This paper examines factors underlying firms' capital and current expenditures on environmental protection. Using micro data from Ireland's industry sector over the period 2008-2016, we analyse a range of such factors including firm characteristics, environmental regulations, competition and spillover effects from firms with investment and spending on environmental protection within the same industry or within the same region. 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. Industry competition incentivizes firms to invest in equipment for cleaner technologies. Further, our results indicate that the propensity of firms to invest in equipment for pollution control and to spend on environmental protection are higher for more energy-intensive firms. Finally, our results uncover significant positive spillover effects from firms with capital expenditures as well as from firms with current expenditures on environmental protection in the same industry or the same region on firms' decisions to invest and spend on environmental protection.

Keywords: Corporate expenditures on environmental protection, environmental regulations, peer effects, multinational activity

JEL Classification: D22, F23, L21, L53, Q55

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1. Introduction

The transition to a climate-neutral economy and a more sustainable long-term economic growth require firms to invest in equipment for pollution control and cleaner technologies. Understanding what drives firms' decisions to spend on environmental protection is important for the design of policy measures aimed at improving environmental quality and resource efficiency.

This paper examines factors underlying firms' capital and current expenditures on environmental protection in the industry sector in Ireland. Specifically, we analyse the role of firm characteristics, environmental regulations, competition and spillover effects from firms in the same industry or the same region.

Previous evidence indicates that firms' decisions to spend on environmental protection are affected by their size, export participation, ownership, energy intensity in production and environmental regulations. 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.

We build on and extend these results by using a longer and more recent panel data from Ireland, over the period 2008-2016, and by considering more factors that influence firms' decisions to spend on environmental protection. Further, since Ireland is an open economy with foreign affiliates having parent headquarters in different regions of the world, we investigate if the country of origin of foreign investors also played a role on firms' investment and spending decisions over and above foreign-ownership.

Although regulations are widely thought to increase firms' incentives to invest in environmental protection, related empirical evidence is far from conclusive. By analyzing Irish manufacturers which took part in the pilot phase of the European Union Emissions Trading System (EU ETS), Anderson et al. (2011) 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 had 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, while 24.6% of firms had current expenditures on environmental protection. 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). We revisit the effects of environmental regulations on capital and current expenditures on environmental protection in the case of firms in Ireland's manufacturing and utilities sectors using more recent firm-level data for the period 2008-2016.

Furthermore, a firm's decision to invest in environmental protection may also be affected by decisions of firms in the same industry or in the same region. One possible reason 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 firms' awareness of protecting the environment would be enhanced by observing other firms' investment decisions, and therefore, this increases firms' incentives to invest. 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. However, to the best of our knowledge, there is no analysis of knowledge spillovers from peer firms on firms' investment in environmental protection.

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. Exporters are more likely to spend on environment protection. Local firms are more likely to invest in environmental protection than foreign-owned firms. This result might reflect the fact that these foreign affiliates have already adequate equipment for air pollution control and cleaner technologies and there is no need for further investment. The energy intensity of firms' production is positively linked to the propensity to invest in pollution control and to spend on environmental protection.

We also find that industry competition incentivizes firms to invest in equipment linked to cleaner technologies. While environmental regulations incentivize firms to spend on environmental protection, they do not appear to have a statistically significant impact on the decision of firms to invest in equipment for pollution control and in equipment linked to cleaner technologies. This insignificant impact might also reflect aggregation bias given that we use measures of industry rather than firm-level exposure to environmental regulations. Further, our results indicate that the propensities of firms to invest in equipment for pollution control and to spend on environmental protection are higher for more energy-intensive firms. Finally, our results uncover significant positive spillover effects from firms with investment and spending on environmental protection in the same industry or the same region on firms' propensity to invest in or spend on 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. 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), investment linked to cleaner technologies (CT), and current expenditures on environmental protection (Env). The first two investment variables are obtained from reported information on changes in capital assets, while the last one is reported as current expenditure (intermediate consumption).

However, not all enterprises are required to provide details on their environmental protection capital and current expenditures. 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 with over 20 persons engaged requested to respond to Form F, represent around 49% of the total number of enterprises in the data. Table 1 summarizes the proportion of enterprises returning Form C and Form F, and the distribution of their size (measured as the number of persons engaged).

Table 1: Proportion of firms returning Form F and distribution of firm size

Survey questionnaire	Proportion	Total persons engaged				
		p5	p10	p50	p90	p95
Form C	50.9%	3	3	8	18	22
Form F	49.1%	18	21	53	286	475

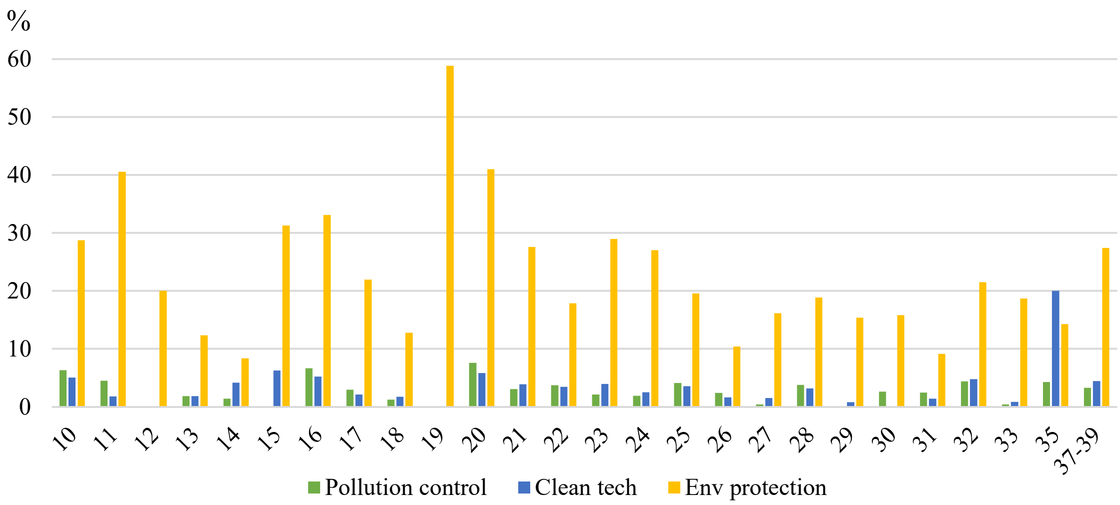
Source: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
Note: There are around 2000 enterprises answering the CIP survey each year, excluding enterprises with less than 3 persons engaged.

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 descriptive analysis in this section is based on firms with 20 or more persons engaged since information on capital and current expenditures on environmental protection is not collected for firms with less than 20 persons engaged.

However, not responding to Form F does not mean the enterprise does not have investment or expenditure on 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.

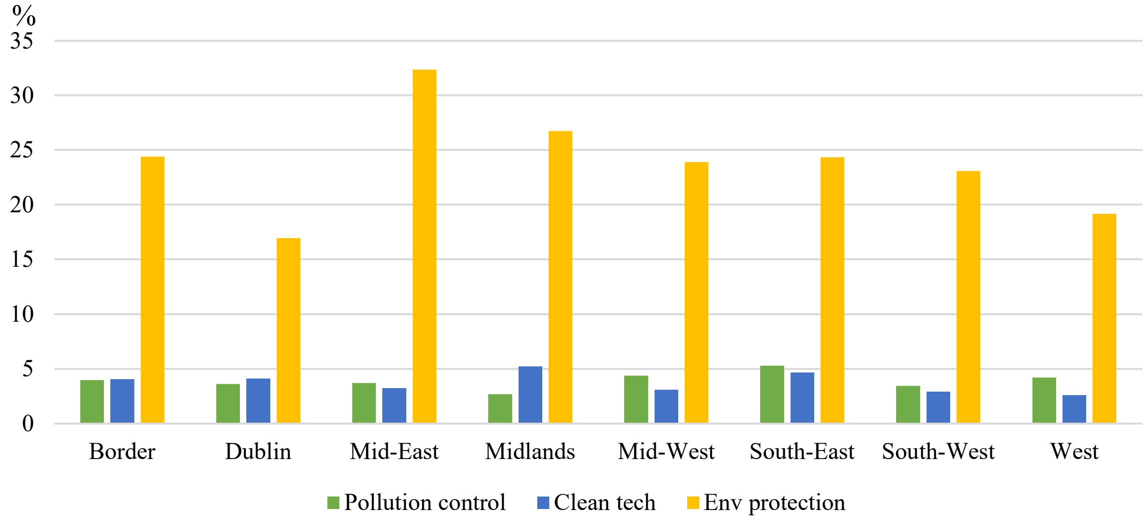
Figure 1 shows the rates of capital and current expenditures on environmental protection by industry, where an industry is defined as the 2-digit NACE Rev.2. classification. On average, only 3.9% of firms invested in equipment for pollution control in a year and only 3.7% of firms invested in equipment linked to cleaner technologies. However, a larger proportion of firms report current expenditures on environmental protection, namely, 23.1%. These results are similar to the capital and current expenditure 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 24.6% for environmental protection expenditure). However, the capital and current expenditure rates are much lower than figures reported by Anderson et al. (2011).

Figure 1: Capital and current expenditures on environmental protection 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.

Figure 2: Capital and current expenditures on environmental protection rates by region, 2008-2016

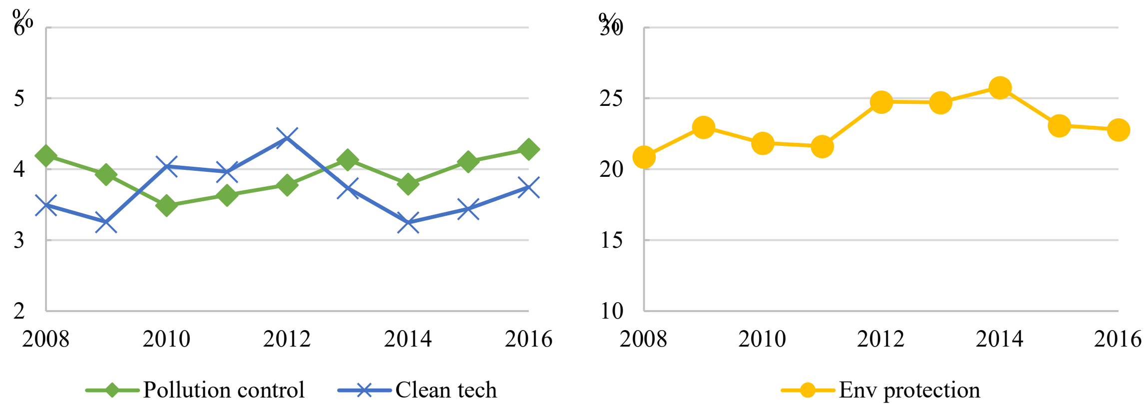


Source: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

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.

Figure 2 shows the proportion of firms that invest or spend on environmental protection by region of location (NUTS 3). The proportion of firms with current expenditures on environmental protection is the highest in the Mid-East region, 32.4%. Dublin and the West regions have the lowest proportion of firms with current expenditures on environment protection, 17.0 % and 19.2% respectively. On the other hand, 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).

Figure 3: The proportion of firms with capital and current expenditures on environmental protection in all firms by year, 2008-2016

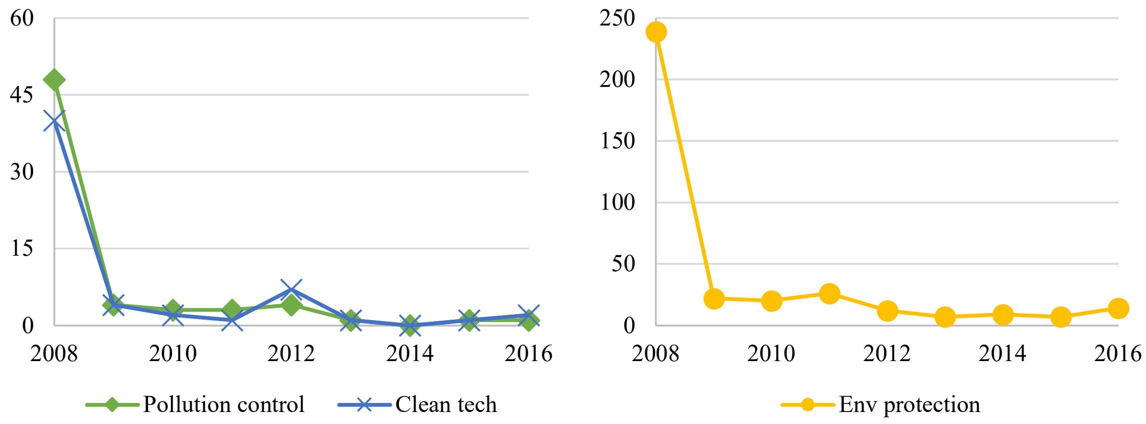


Source: Authors' calculations based on data from the Census of Industrial Production, Central Statistics Office, Ireland.

Figure 3 presents the overall trend of the proportion of firms that invest/spend on environmental protection. The rates of investment/expenditures on environmental protection 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%, and more firms (over 20%) report current expenditures on environmental protection.

As the investment/expenditure rates are flat over time, we further investigate if firms' investment /spending rates are persistent over time. Figure 4 shows the number of firms by the first year we observe a positive investment/spending on environmental protection during the analysed period. It shows that for the majority of firms that ever invest/spend during the analysed period, we observe a large number in 2008, while there are very few new investors/firms with current expenditures on environmental protection in later years. For example, around 250 unique firms in our dataset have already started to spend on environmental protection in 2008, while only 22 firms started to spend in 2009. In 2013, this number further decreased to around 10. This pattern is observed for investments as well.

Figure 4: Distribution of firms by the first year with positive capital and current expenditures on environmental protection in the data set



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

Combining the flat investment/spending rates over time shown in Figure 3, the descriptive analysis suggests that firms' spending 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.

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, which may be the case because they are more productive relative to firms serving only the domestic market.

We consider these variables in our analysis. In addition to using binary variables for foreign ownership and exporting, we also include more detailed information in one of our model specifications. We separate the location of a firm's headquarter into six categories: local (Ireland), the UK, the Eurozone, 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 behavior by firm group.

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.

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:

$$HHI_j = \sum_i s_{ij}^2 , \ s_{ij} = \frac{x_{ij}}{\sum_i x_{ij}} \tag{1}$$

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 and spend on 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.[2] 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

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

studies (see for example, Dechezleprêtre et al. 2018).[3] Another relevant environmental regulation is the Integrated Pollution Control (IPC) program, which aims to reduce emissions to air, water and land, and reduce emission and increase energy efficiency.[4] 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/spend on environmental protection.

Firms' decisions to invest in environmental protection are highly persistent. As shown in the descriptive analysis, most firms that invested in 2009 and onwards are firms that have invested in 2008, 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 or spent on 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 (or spend) and average characteristics for these firms by excluding firm *i*. This approach is used to uncover whether a firm's decision to invest/spend 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/spend 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.

As discussed before, the majority of variables are only available for firms with 20 and more persons engaged. 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

[3] 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.

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

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. Table 2 provides the definitions and summary statistics for these variables.

Table 2: Summary statistics

Variable	Description	Mean	Std.Dev.	Min	Max
Form F firms (firm-year observations: 8,151)					
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
Env	Current expenditures on environment protection (1000 euro)	30.80	245.79	0.00	11518.94
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
Env_d	Dummy =1 if firm reports current expenditures on environmental protection	0.23	0.42	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
Age2	Age of a firm squared	1189.82	1454.27	1	18225
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_g	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_g	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: 1,144)					
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
Joint08 (Env)	Dummy, =1 if firm has current expenditures on environmental protection in 2008	0.21	0.41	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

Table 2: Summary statistics (ctd.)

Variable	Description	Mean	Std.Dev.	Min	Max
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_Env	Proportion of firms that spends on env protection in the same industry (NACE Rev.2. 2 digit) other than a given firm (*100)	13.42	8.12	0.00	100.00
Peer_r_Env	Proportion of firms that spends on env protection in the same region other than a given firm (*100)	11.94	3.18	6.72	20.54
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.

3. Econometric Methodology

3.1 Baseline model specifications

We first consider which types of enterprises are more likely to invest in or spend on environmental protection. Second, we consider whether a firm's decision is influenced by the investment behavior of peer firms.

Since only firms with 20 or more persons engaged report their capital and current expenditures on 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 (spend) conditional on filling Form F:

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

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

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

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 or spends on 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/spend on environmental protection. We investigate two types of peer effects: firms in the same sector, and 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 $\widehat{\mathrm{E}_{-\iota}}(y_t|g)$, 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

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

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/spending decision. The primary instrument we use is the average 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/spend on environment protection than foreign-owned firms and thus, a higher average 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 this firms' decision to invest or spend on environment protection so this instrument is exogenous to the system.

In fact, the average rate of local firms is a strong instrument for an industry peer effect, as in the first stage the F statistics is greater than 40 in all models. However, it is much weaker when used as an instrument for the spatial peer effect. To account for this, we further include the average proportion of exporters in the same region (Peer_r_exporter) and the average energy intensity in the same region (Peer_r_fuel) as additional instruments. These two instruments are also likely to be exogenous following the same logic as in the case of the proportion of local firms in a peer group. For example, whether a firm *i* exports or not (or its energy intensity) is unlikely to be affected by firm *j*'s investment decision to invest/spend on environmental protection.

If we believe that 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' capital or current expenditures on environmental protection will increase (decrease) a firm's probability to invest/spend on 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 Tables 3a and 3b. Table 3a shows the results of the outcome equation and 3b shows the results of the selection 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/spending (M1), which is included in the second column (M2). 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 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. In the selection equations, 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. For comparison, we estimate a probit model on firms with 20 and more persons engaged, removing the selection stage. Results are very similar to those in Table 3a and are shown in Table A1 in the Appendix. 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.

In the second set of model specifications (M3), we include detailed information on the country of origin and export destinations. All other variables are the same as the ones used in the M2 model mentioned above. In Table 4, we present the estimated coefficients for export destinations and headquarter location. The full set of estimates are shown in Table A2 in the Appendix. The coefficients in the M3 model are similar to those in the M2 model (Table 3a).

Our main results are summarized as follows. Estimates obtained with the Heckman selection models suggest that firms that invested/spent on environmental protection in 2008 are more likely to continue to invest/spend 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. Environmental regulations (EU ETS) have positive effects on firms' propensity to spend on environmental protection, while they have no significant effect on firms' propensity to invest in equipment for pollution control or in equipment linked to cleaner technologies. Higher energy intensity appears to have a significant effect on firms' decision to invest in equipment for pollution control and on current expenditures on environmental protection 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.

Moreover, it appears that firms' position in the corporation group matters. 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 above other factors. However, firms' decisions to invest or spend on environmental protection are negatively correlated with labour productivity. Further, such decisions do not appear to be influenced by their investment in other tangible or intangible assets, and by workers' skills.

Our results indicate that competition within industry affects firms' decision to invest in environmental protection. The estimates shown in columns (3) and (4) indicate that firms with a higher market share in an industry and in industries with a higher market concentration are more likely to invest in equipment linked to cleaner technologies.

Table 3a: Determinants of firms' propensity to invest/spend on environmental protection conditional on firms filling Form F (outcome equation)

	PC		CT		Env	
	(1)	(2)	(3)	(4)	(5)	(6)
Joint08		0.571***		0.805***		1.314***
		(0.105)		(0.116)		(0.069)
GVA	0.197***	0.189***	0.131***	0.127**	0.243***	0.175***
	(0.042)	(0.042)	(0.053)	(0.054)	(0.057)	(0.054)
ETS	-0.014	-0.053	0.15	0.104	0.342***	0.235**
	(0.176)	(0.16)	(0.154)	(0.148)	(0.113)	(0.098)
Energy industry	-0.077	-0.039	1.143***	1.165***	-0.439	-0.077
	(0.321)	(0.318)	(0.177)	(0.169)	(0.364)	(0.288)
Age	0.006	0.005	0.005	0.007	0.004	-0.009*
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)
Age2	0.000	0.000	0.000	0.000	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share	-0.261	-0.245	1.805***	1.812***	-0.017	-0.541
	(0.596)	(0.598)	(0.625)	(0.596)	(0.565)	(0.496)
HHI	-0.455	-0.365	-1.840***	-1.846***	-0.289	0.042
	(0.504)	(0.487)	(0.648)	(0.617)	(0.363)	(0.349)
Skills	-0.011	-0.016	0.000	0.044	0.046	-0.012
	(0.142)	(0.143)	(0.17)	(0.18)	(0.119)	(0.127)
Importer	0.250**	0.263**	0.219*	0.244**	0.085	0.021
	(0.118)	(0.123)	(0.113)	(0.116)	(0.13)	(0.123)
Exporter	0.081	0.082	0.134	0.135	0.335***	0.316***
	(0.083)	(0.079)	(0.085)	(0.085)	(0.089)	(0.084)
Supply chain link	0.195**	0.207**	0.190**	0.201**	0.175*	0.167*
	(0.084)	(0.09)	(0.088)	(0.086)	(0.095)	(0.088)
Local	0.373***	0.372***	0.507***	0.511***	0.356***	0.332***
	(0.118)	(0.119)	(0.111)	(0.115)	(0.084)	(0.086)
Energy intensity	0.205***	0.204***	0.076	0.086	0.223***	0.167***
	(0.058)	(0.058)	(0.068)	(0.066)	(0.062)	(0.06)
Intangible_g	-0.039	-0.043	0.035	0.022	-0.023	-0.053
	(0.071)	(0.072)	(0.096)	(0.09)	(0.054)	(0.06)
Tangible_g	0.053	0.049	0.051	0.039	0.045	0.073
	(0.074)	(0.071)	(0.097)	(0.095)	(0.049)	(0.051)
Productivity	-0.137**	-0.130*	-0.091	-0.098	-0.163***	-0.096
	(0.066)	(0.067)	(0.071)	(0.069)	(0.063)	(0.063)
Constant	-3.307***	-3.288***	-2.839***	-3.090***	-2.879***	-2.367***
	(0.48)	(0.47)	(0.566)	(0.581)	(0.448)	(0.419)
Firm-year observations	8,151	8,151	8,151	8,151	8,151	8,151
atanh rho	-0.026	-0.03	-0.283**	-0.273**	0.041	0.037
	(0.124)	(0.125)	(0.128)	(0.133)	(0.075)	(0.068)

Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
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 has participated in the corresponding environment protection investment/spending or not in 2008. * p<.1; ** p<.05; *** p<.01. atanh rho = 0.5*ln((1+rho)/(1-rho)).

Table 3b: Determinants of firms' probability to respond to Form F (selection equation)

	PC		CT		Env	
	(1)	(2)	(3)	(4)	(5)	(6)
Selection equation:						
GVA	0.129***	0.129***	0.129***	0.129***	0.129***	0.129***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)
Emp20	2.399***	2.399***	2.394***	2.394***	2.402***	2.402***
	(0.059)	(0.059)	(0.059)	(0.059)	(0.058)	(0.059)
Capital	0.079***	0.079***	0.080***	0.080***	0.078***	0.078***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Local	-0.684***	-0.684***	-0.686***	-0.686***	-0.681***	-0.682***
	(0.099)	(0.099)	(0.100)	(0.100)	(0.099)	(0.099)
Constant	-2.238***	-2.238***	-2.234***	-2.235***	-2.238***	-2.239***
	(0.117)	(0.117)	(0.117)	(0.117)	(0.117)	(0.117)
Firm-year observations	16,199	16,199	16,199	16,199	16,199	16,199
Wald test rho=0	0.046	0.057	4.866**	4.228**	0.303	0.294
Log-likelihood	-5.40E+03	-5.30E+03	-5.30E+03	-5.30E+03	-8.20E+03	-7.60E+03

Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
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 capital/current expenditures on environmental protection in 2008. * p<.1; ** p<.05; *** p<.01.

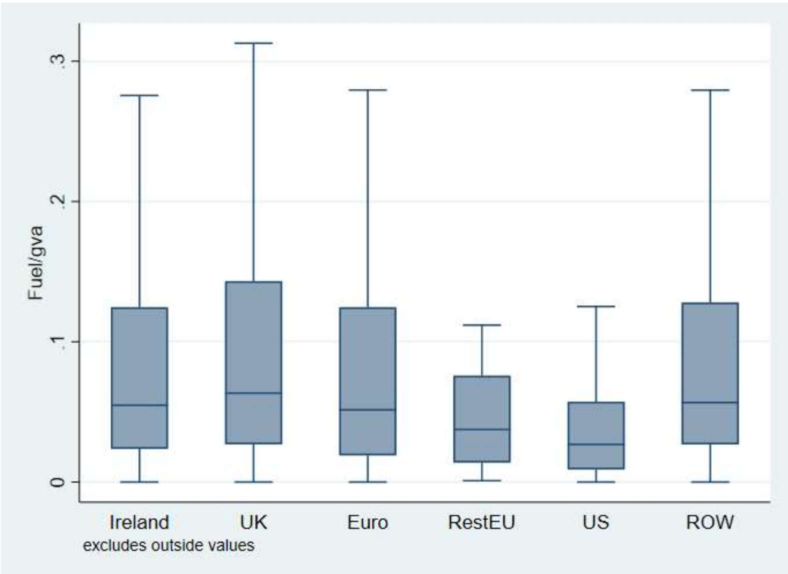
Table 4: Determinants of firms' propensity to invest in/spend on environmental protection, detailed exporting destination and country of origin

	Full sample with selection			Selected sample only		
	PC	CT	Env	PC	CT	Env
	(1)	(2)	(3)	(4)	(5)	(6)
Export destination:						
Ex_uk	0.152**	0.193**	0.271***	0.152**	0.210**	0.268***
	(0.077)	(0.08)	(0.071)	(0.076)	(0.082)	(0.07)
Ex_resteu	-0.024	-0.028	0.021	-0.024	-0.028	0.02
	(0.082)	(0.101)	(0.075)	(0.082)	(0.103)	(0.075)
Ex_usa	-0.287***	-0.127	-0.190*	-0.287***	-0.134	-0.188*
	(0.09)	(0.121)	(0.109)	(0.09)	(0.123)	(0.109)
Ex_row	0.075	0.011	0.027	0.075	0.01	0.027
	(0.094)	(0.091)	(0.064)	(0.094)	(0.092)	(0.064)
Ex_euro	0.109	-0.042	0.119	0.109	-0.037	0.117
	(0.084)	(0.086)	(0.103)	(0.085)	(0.086)	(0.103)
HQ location:						
UK	-0.182	-0.964***	-0.111	-0.182	-0.935***	-0.119
	(0.215)	(0.351)	(0.177)	(0.213)	(0.351)	(0.176)
Euro zone	-0.406**	-0.413**	-0.296**	-0.406***	-0.375**	-0.302**
	(0.158)	(0.188)	(0.127)	(0.157)	(0.189)	(0.128)
Rest EU	-0.358	-0.197	-0.002	-0.358	-0.162	-0.009
	(0.565)	(0.405)	(0.345)	(0.566)	(0.412)	(0.345)
USA	-0.348**	-0.499**	-0.447***	-0.348**	-0.477**	-0.449***
	(0.137)	(0.202)	(0.107)	(0.138)	(0.198)	(0.107)
ROW	-0.347	-0.312*	-0.345	-0.347	-0.283	-0.349
	(0.234)	(0.183)	(0.219)	(0.233)	(0.184)	(0.219)

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

Importing firms are more likely to invest in equipment for pollution control and cleaner technologies while exporting firms are more likely to spend on environmental protection, as shown in Table 3a. Furthermore, when we break down exports by country of destination, Table 4 suggests that firms that export to the UK are more likely to invest and spend on 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 and to spend on environmental protection relative to firms that do not export to the US. Exporting to other areas does not have a significant impact on firms' investment/spending on environmental protection.

Figure 5: Energy intensity for local firms and foreign affiliates by country of origin



Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
Note: The box plot shows the mean, 75th percentile, 25th percentile and the upper and lower adjacent values.

Foreign-owned firms are less likely to invest in environmental protection relative to local (Irish-owned) firms (Table 3a). This result is driven mainly by firms with headquarters in the US and the Eurozone (and UK for investment in equipment for cleaner technologies) as shown in Table 4. One possible explanation is that these firms already 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). Figure 5 shows 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 unit output, 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 to that of Irish-owned firms. These results are consistent with evidence from 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; Collins and Harris 2005).

4.2 Peer effects

As discussed above, peer firms' decisions may affect a firm's decision to invest or spend on environmental protection, as a firm may learn from peer firms' decisions. Since the peer effect variable is endogenous, we use the average peer firm characteristics as instrumental variables. Tables 5 and 6 present the estimates of peer firm effects on firms investment/spending on environmental protection. For each dependent variable, we list the results from the OLS regression (M4) in the first column and the IV regression (M5) in the second column. Table 5 presents the set of results corresponding to peer firms in the same industry. Table 6 shows the estimated peer effects when peer firms in the same NUTS 3 region are considered.

The main variable of interest in these tables is the peer rate (the investment/spending rate of peer firms in the same industry or region). Table 5 suggests that firms' decision to invest in equipment for pollution control and in cleaner technologies and to spend on environmental protection are positively affected by other firms' decision in the same industry. Comparing the IV estimates with the corresponding OLS results, the coefficients become larger, which perhaps is due to the negative correlation between the peer rate and omitted variables.

Interestingly, Table 6 suggests that firms also learn from other firms in the same region, as they are close to each other geographically. Spatial peer effects are only present in the cases of investment in equipment for pollution control and equipment linked to cleaner technologies, while they are not significant in the case of current expenditures on environmental protection. One possible explanation is that investment is riskier than intermediate consumption (current expenditures) so that firms are more likely to learn from other firms, conditional on firms' own characteristics.

Taken together, these findings suggest that peer firms' investment in/spending (within industry or spatial, within region) on environmental protection could increase a firm's awareness and engagement, as firms learn from each other.

Table 5: Industry peer effects

	PC		CT		Env	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Peer rate	0.044***	0.103**	-0.001	0.123**	0.012**	0.034***
	(0.013)	(0.043)	(0.023)	(0.057)	(0.005)	(0.011)
Joint08	0.564***	0.543***	0.805***	0.781***	1.318***	1.301***
	(0.105)	(0.119)	(0.116)	(0.106)	(0.069)	(0.064)
GVA	0.174***	0.151***	0.127**	0.089	0.153***	0.109*
	(0.039)	(0.043)	(0.052)	(0.054)	(0.052)	(0.062)
ETS	-0.051	-0.034	0.104	0.075	0.185*	0.086
	(0.141)	(0.136)	(0.148)	(0.142)	(0.101)	(0.109)
Energy industry	-0.021	-0.031	1.175***	0.019	0.059	0.283
	(0.322)	(0.264)	(0.28)	(0.555)	(0.294)	(0.452)
Age	0.005	0.005	0.007	0.007	-0.009*	-0.009*
	(0.005)	(0.004)	(0.006)	(0.007)	(0.005)	(0.005)
Age2	0.000	0.000	0.000	0.000	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share	0.075	0.445	1.802***	2.469***	-0.002	0.845
	(0.569)	(0.72)	(0.575)	(0.738)	(0.554)	(0.744)
HHI	-0.496	-0.591	-1.842***	-1.867***	-0.375	-0.953*
	(0.516)	(0.554)	(0.591)	(0.578)	(0.4)	(0.516)
Skills	0.017	0.068	0.043	0.135	0.032	0.107
	(0.138)	(0.151)	(0.182)	(0.175)	(0.122)	(0.126)
Importer	0.267**	0.263**	0.244**	0.243*	0.029	0.041
	(0.12)	(0.126)	(0.116)	(0.131)	(0.119)	(0.116)
Exporter	0.071	0.053	0.135	0.118	0.308***	0.293***
	(0.078)	(0.083)	(0.085)	(0.096)	(0.082)	(0.076)
Supply chain link	0.205**	0.199**	0.202**	0.181*	0.166*	0.159*
	(0.09)	(0.091)	(0.085)	(0.097)	(0.088)	(0.091)
Local	0.351***	0.310**	0.512***	0.411***	0.323***	0.297***
	(0.116)	(0.142)	(0.114)	(0.138)	(0.084)	(0.086)
Energy intensity	0.178***	0.136*	0.087	0.008	0.130**	0.063
	(0.054)	(0.071)	(0.063)	(0.09)	(0.058)	(0.071)
Intangible_g	-0.036	-0.027	0.022	0.025	-0.055	-0.057
	(0.072)	(0.081)	(0.09)	(0.113)	(0.059)	(0.062)
Tangible_g	0.048	0.047	0.039	0.043	0.072	0.067
	(0.071)	(0.084)	(0.095)	(0.121)	(0.051)	(0.052)
Productivity	-0.130**	-0.126**	-0.098	-0.101	-0.098	-0.093
	(0.065)	(0.061)	(0.068)	(0.071)	(0.062)	(0.065)
Mill's ratio	-0.014	0.002	-0.273**	-0.245	0.043	0.054
	(0.123)	(0.118)	(0.132)	(0.346)	(0.069)	(0.062)
Constant	-3.374***	-3.471***	-3.088***	-3.256***	-2.439***	-2.559***
	(0.445)	(0.44)	(0.584)	(0.541)	(0.422)	(0.463)
Firm-year observations	16,199	16,199	16,199	16,199	16,199	16,199
atanh rho		-0.13		-0.232**		-0.168**
		(0.094)		(0.108)		(0.072)
ln(sigma)		0.652***		0.486***		1.843***
		(0.057)		(0.064)		(0.101)
chi2	205.1	250.1	.	793.7	1003.6	1152.7
First stage F stats		107.39		58.70		43.67

Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
Notes: Year dummy is included in the outcome equation. Result for selection equation is not shown. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had capital/current expenditures on environmental protection in 2008. * p<.1; ** p<.05; *** p<.01. The null hypothesis for the exogeneity of peer rate is H : atanh rho=0. atanh rho = 0.5*ln((1+rho)/(1-rho)). First stage F stats reports the F statistics of IVs in the first stage regression.

Table 6: Spatial peer effects

	PC		CT		Env	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Peer rate	-0.038	0.196***	-0.009	0.229*	0.013	-0.005
	(0.043)	(0.07)	(0.032)	(0.13)	(0.011)	(0.028)
Joint08	0.569***	0.570***	0.806***	0.792***	1.309***	1.316***
	(0.104)	(0.105)	(0.116)	(0.108)	(0.069)	(0.068)
GVA	0.191***	0.180***	0.127**	0.130**	0.174***	0.175***
	(0.041)	(0.045)	(0.051)	(0.053)	(0.053)	(0.052)
ETS	-0.053	-0.055	0.104	0.099	0.232**	0.236**
	(0.16)	(0.179)	(0.148)	(0.143)	(0.098)	(0.11)
Energy sector	-0.047	0.014	1.166***	1.122***	-0.06	-0.08
	(0.316)	(0.266)	(0.169)	(0.194)	(0.298)	(0.434)
Age	0.005	0.004	0.007	0.007	-0.009*	-0.009
	(0.005)	(0.006)	(0.006)	(0.007)	(0.005)	(0.006)
Age2	0.000	0.000	0.000	0.000	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share	-0.263	-0.172	1.814***	1.782***	-0.535	-0.544
	(0.598)	(0.664)	(0.594)	(0.669)	(0.495)	(0.577)
HHI	-0.359	-0.369	-1.848***	-1.793***	0.037	0.038
	(0.485)	(0.643)	(0.616)	(0.684)	(0.347)	(0.354)
Skills	-0.016	-0.01	0.043	0.042	-0.006	-0.016
	(0.143)	(0.154)	(0.181)	(0.178)	(0.127)	(0.112)
Importer	0.263**	0.258*	0.243**	0.258**	0.024	0.021
	(0.123)	(0.136)	(0.117)	(0.119)	(0.124)	(0.119)
Exporter	0.081	0.08	0.135	0.124	0.309***	0.317***
	(0.079)	(0.084)	(0.085)	(0.087)	(0.083)	(0.089)
Supply chain link	0.206**	0.195*	0.202**	0.202**	0.168*	0.169*
	(0.09)	(0.103)	(0.086)	(0.098)	(0.088)	(0.088)
Local	0.375***	0.337**	0.511***	0.483***	0.330***	0.333***
	(0.119)	(0.131)	(0.115)	(0.121)	(0.086)	(0.089)
Energy intensity	0.207***	0.194***	0.087	0.079	0.166***	0.166**
	(0.057)	(0.07)	(0.066)	(0.081)	(0.06)	(0.065)
Intangible_g	-0.045	-0.038	0.022	0.026	-0.051	-0.054
	(0.072)	(0.082)	(0.09)	(0.105)	(0.059)	(0.065)
Tangible_g	0.048	0.051	0.039	0.044	0.074	0.074
	(0.07)	(0.081)	(0.095)	(0.138)	(0.051)	(0.048)
Productivity	-0.132**	-0.121*	-0.098	-0.098	-0.094	-0.097
	(0.066)	(0.068)	(0.069)	(0.074)	(0.063)	(0.06)
Mill's ratio	-0.031	-0.032	-0.274**	-0.262	0.037	0.036
	(0.125)	(0.128)	(0.133)	(0.34)	(0.068)	(0.067)
Constant	-3.225***	-3.563***	-3.070***	-3.439***	-2.520***	-2.296***
	(0.476)	(0.522)	(0.593)	(0.597)	(0.465)	(0.539)
Firm-year observations	16,199	16199	16,199	16,199	16,199	16,199
atanh rho		-0.213***		-0.215*		0.05
		(0.066)		(0.119)		(0.07)
ln(sigma)		-0.254***		-0.174***		0.873***
		(0.007)		(0.024)		(0.012)
chi2	.	146.5	.	804.4	954.0	858.2
First stage F stats		826.38		327.10		486.97

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

Notes: Year dummies are included in the outcome equation. Results for the selection equation are not shown. Robust standard errors are clustered at NACE Rev.2 3-digit level. * p<.1; ** p<.05; *** p<.01. The IVs for spatial peer effects are peer_r_local, peer_r_exporter and peer_r_fuel, as peer_r_local alone is not strong enough based on the first stage F statistics (<10). The null hypothesis for the exogeneity of peer rate is H_0: atanh rho=0. atanh rho = 0.5*ln((1+rho)/(1-rho)). First stage F stats reports the F statistics of IVs in the first stage regression.

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 than 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' capital and current expenditures on environmental protection. 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 a range of such factors including firm characteristics, environmental regulations, competition and peer effects.

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 Eurozone. 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. The energy intensity of firms' production is positively linked to their propensity to invest in equipment for pollution control and their current expenditures on environmental protection.

Within industry competition measured as market share and market concentration is an important driver of firms' investment in equipment linked to cleaner technologies. While environmental regulations incentivize firms to spend on environmental protection, they do not appear to have a significant impact on firms' investment in environmental protection. 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 and spending on environmental protection in the same industry or the same region on firms' propensity to invest and spend on environmental protection.

To the extent that incentivizing more firms to invest in environmental protection could contribute to improved environmental quality, 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 facilitating learning from firms with green investments within the same industry and within the same region could foster firms' investments in environmental protection.

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Appendix

Table A1: Determinants of firms' propensity to invest in environmental protection, probit model based on firms with more than 20 persons engaged (Form F firms)

	PC		CT		Env	
	(1)	(2)	(3)	(4)	(5)	(6)
Joint08		0.571***		0.818***		1.314***
		(0.104)		(0.118)		(0.69)
GVA	0.201***	0.193***	0.165***	0.160***	0.237***	0.169***
	(0.038)	(0.038)	(0.045)	(0.046)	(0.053)	(0.049)
ETS	-0.013	-0.051	0.159	0.11	0.340***	0.233**
	(0.176)	(0.16)	(0.157)	(0.151)	(0.113)	(0.099)
Energy industry	-0.08	-0.043	1.105***	1.125***	-0.43	-0.07
	(0.318)	(0.314)	(0.176)	(0.169)	(0.363)	(0.288)
Age	0.006	0.005	0.006	0.007	0.004	-0.009*
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)
Age2	0.000	0.000	0.000	0.000	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share	-0.27	-0.256	1.766***	1.771***	-0.007	-0.533
	(0.607)	(0.612)	(0.639)	(0.609)	(0.562)	(0.496)
HHI	-0.457	-0.366	-1.846***	-1.843***	-0.288	0.043
	(0.505)	(0.487)	(0.654)	(0.623)	(0.363)	(0.349)
Skills	-0.01	-0.016	0.000	0.044	0.046	-0.012
	(0.142)	(0.143)	(0.172)	(0.182)	(0.119)	(0.127)
Importer	0.253**	0.265**	0.239**	0.263**	0.082	0.019
	(0.12)	(0.125)	(0.112)	(0.116)	(0.132)	(0.124)
Exporter	0.083	0.084	0.161*	0.159*	0.332***	0.313***
	(0.083)	(0.079)	(0.087)	(0.087)	(0.088)	(0.083)
Supply chain link	0.195**	0.206**	0.190**	0.202**	0.176*	0.168*
	(0.084)	(0.09)	(0.09)	(0.087)	(0.095)	(0.088)
Local	0.370***	0.369***	0.477***	0.482***	0.360***	0.335***
	(0.119)	(0.12)	(0.109)	(0.113)	(0.084)	(0.086)
Energy intensity	0.204***	0.204***	0.073	0.082	0.223***	0.167***
	(0.058)	(0.058)	(0.068)	(0.066)	(0.062)	(0.06)
Intangible_g	-0.038	-0.041	0.04	0.028	-0.025	-0.055
	(0.072)	(0.073)	(0.096)	(0.09)	(0.054)	(0.059)
Tangible_g	0.053	0.049	0.06	0.047	0.044	0.072
	(0.074)	(0.071)	(0.098)	(0.096)	(0.049)	(0.05)
Productivity	-0.140**	-0.134**	-0.121*	-0.127**	-0.157**	-0.091
	(0.067)	(0.067)	(0.066)	(0.064)	(0.061)	(0.061)
Constant	-3.335***	-3.319***	-3.132***	-3.369***	-2.831***	-2.322***
	(0.47)	(0.46)	(0.543)	(0.551)	(0.436)	(0.405)
Firm-year observations	8,151	8,151	8,151	8,151	8,151	8,151
pseudo R^2	0.053	0.064	0.079	0.106	0.076	0.194
Log-likelihood	-1.30E+03	-1.30E+03	-1.20E+03	-1.20E+03	-4.10E+03	-3.60E+03
chi2	142.97	156.36	718.78	1096.71	205.12	960.89

Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
Note: Year dummy is included in the outcome equation. Robust standard errors are clustered at NACE Rev.2 3-digit level. Joint08 indicates if firm had capital/current expenditures on environmental protection in 2008. * p<.1; ** p<.05; *** p<.01.

Table A2: Determinants of firms' probability to invest in environmental protection, detailed exporting destination and location of parent firms headquarter.

	Full sample with selection			Selected sample only		
	PC	CT	Env	PC	CT	Env
	(1)	(2)	(3)	(4)	(5)	(6)
Joint08	0.577***	0.812***	1.291***	0.577***	0.824***	1.292***
	(0.111)	(0.115)	(0.072)	(0.11)	(0.117)	(0.072)
GVA	0.197***	0.141***	0.191***	0.197***	0.174***	0.181***
	(0.041)	(0.054)	(0.047)	(0.036)	(0.047)	(0.041)
ETS	-0.052	0.084	0.223**	-0.052	0.088	0.221**
	(0.159)	(0.15)	(0.097)	(0.159)	(0.153)	(0.097)
Energy industry	-0.119	1.019***	-0.173	-0.119	0.973***	-0.16
	(0.321)	(0.155)	(0.277)	(0.317)	(0.153)	(0.277)
Age	0.004	0.006	-0.010**	0.004	0.006	-0.010**
	(0.004)	(0.006)	(0.005)	(0.004)	(0.006)	(0.005)
Age2	0.000	0.000	0.000**	0.000	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share	-0.314	1.721***	-0.655	-0.313	1.673***	-0.639
	(0.547)	(0.57)	(0.48)	(0.561)	(0.583)	(0.481)
HHI	-0.29	-1.699***	0.115	-0.29	-1.689***	0.115
	(0.459)	(0.59)	(0.329)	(0.458)	(0.596)	(0.329)
Skills	0.027	0.063	0.018	0.027	0.064	0.017
	(0.128)	(0.17)	(0.115)	(0.129)	(0.171)	(0.115)
Importer	0.248**	0.258**	0.055	0.247**	0.281**	0.051
	(0.114)	(0.12)	(0.122)	(0.116)	(0.119)	(0.123)
Supply chain link	0.208**	0.215***	0.168**	0.208**	0.215***	0.168**
	(0.082)	(0.081)	(0.082)	(0.082)	(0.082)	(0.082)
Energy intensity	0.193***	0.079	0.164***	0.193***	0.075	0.164***
	(0.057)	(0.065)	(0.056)	(0.057)	(0.065)	(0.056)
Intangible_g	-0.02	0.05	-0.029	-0.02	0.058	-0.032
	(0.073)	(0.098)	(0.061)	(0.074)	(0.098)	(0.06)
Tangible_g	0.048	0.045	0.075	0.048	0.053	0.073
	(0.071)	(0.096)	(0.049)	(0.071)	(0.097)	(0.049)
Productivity	-0.135**	-0.1	-0.102*	-0.135**	-0.128**	-0.094*
	(0.066)	(0.071)	(0.058)	(0.066)	(0.065)	(0.056)
Cons	-3.177***	-2.945***	-2.219***	-3.174***	-3.253***	-2.143***
	(0.462)	(0.531)	(0.411)	(0.438)	(0.504)	(0.403)
Export destination:						
Ex_uk	0.152**	0.193**	0.271***	0.152**	0.210**	0.268***
	(0.077)	(0.08)	(0.071)	(0.076)	(0.082)	(0.07)
Ex_resteu	-0.024	-0.028	0.021	-0.024	-0.028	0.02
	(0.082)	(0.101)	(0.075)	(0.082)	(0.103)	(0.075)
Ex_usa	-0.287***	-0.127	-0.190*	-0.287***	-0.134	-0.188*
	(0.09)	(0.121)	(0.109)	(0.09)	(0.123)	(0.109)
Ex_row	0.075	0.011	0.027	0.075	0.01	0.027
	(0.094)	(0.091)	(0.064)	(0.094)	(0.092)	(0.064)
Ex_euro	0.109	-0.042	0.119	0.109	-0.037	0.117
	(0.084)	(0.086)	(0.103)	(0.085)	(0.086)	(0.103)
HQ location:						
UK	-0.182	-0.964***	-0.111	-0.182	-0.935***	-0.119
	(0.215)	(0.351)	(0.177)	(0.213)	(0.351)	(0.176)
Euro zone	-0.406**	-0.413**	-0.296**	-0.406***	-0.375**	-0.302**
	(0.158)	(0.188)	(0.127)	(0.157)	(0.189)	(0.128)
Rest EU	-0.358	-0.197	-0.002	-0.358	-0.162	-0.009
	(0.565)	(0.405)	(0.345)	(0.566)	(0.412)	(0.345)
USA	-0.348**	-0.499**	-0.447***	-0.348**	-0.477**	-0.449***
	(0.137)	(0.202)	(0.107)	(0.138)	(0.198)	(0.107)
ROW	-0.347	-0.312*	-0.345	-0.347	-0.283	-0.349
	(0.234)	(0.183)	(0.219)	(0.233)	(0.184)	(0.219)

Selection equation:						
GVA	0.129***	0.129***	0.129***			
	(0.018)	(0.018)	(0.018)			
Emp20	2.400***	2.395***	2.402***			
	(0.059)	(0.059)	(0.058)			
Capital	0.078***	0.080***	0.078***			
	(0.023)	(0.023)	(0.023)			
Local	-0.684***	-0.685***	-0.681***			
	(0.099)	(0.1)	(0.099)			
Constant	-2.239***	-2.235***	-2.239***			
	(0.117)	(0.117)	(0.117)			
Firm-year observations	16,199	16,199	16,199	8,151	8,151	8,151
atanh rho	0.003	-0.265**	0.057			
	(0.131)	(0.131)	(0.069)			
pseudo R^2				0.073	0.11	0.199
Log-likelihood	-5300	-5200	-7600	-1200	-1200	-3600
chi2	.	.	.	197.7	1225.5	1255.8

Source: Authors' estimates based on data from the Census of Industrial Production, Central Statistics Office, Ireland.
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 capital/current expenditures on environmental protection in 2008. * p<.1; ** p<.05; *** p<.01. atanh rho = 0.5*ln((1+rho)/(1-rho)).