Is there a trade-off between 'dirty' imports and 'clean' innovation?*

Svetlana Batrakova[†] and Antoine Dechezleprêtre[‡]

First Draft: March 2012
This Draft: November 2012

Abstract

We examine the impact of trade with lower-regulated countries on firms' propensity to engage in 'clean' innovation using a newly constructed data set that combines firm-level international trade data with self-reported innovation data for around 400 Irish companies. We find robust evidence that a higher share of 'dirty' imports from BRIC countries significantly decreases firms' propensity to innovate in 'clean' technologies. A one standard deviation increase in the import share of 'dirty' products decreases firms' propensity to introduce an environmental innovation by up to 8 percentage points. This suggests that importing companies are less likely to respond to environmental policies by developing 'clean' technologies. This also means that carbon leakage may not only affect jobs and emissions in the short run, it also affects long-run competitiveness.

Keywords: Imports, Environmental innovation, firm-product analysis
JEL Classification: F18, Q56, D22, L11, C25

---

*We thank Scott Taylor, Farid Toubal, Ron Davies, participants at seminars in Stirling, LSE, Mannheim and Maynooth as well as UCD Trade Group for helpful comments and suggestions. We would like to acknowledge the financial support of the Grantham Foundation for the Protection of the Environment, as well as the Centre for Climate Change Economics and Policy, which is funded by the UK's Economic and Social Research Council and by Munich Re. This paper uses confidential micro datasets of the Central Statistics Office Ireland (CSO). The restricted and controlled access to the data was provided in accordance with the Statistics Act, 1993. We are grateful to Kevin Phelan, Gerry Brady, Carol Anne Hennessy and Ben Berstock for the provided assistance. We are grateful to Justin R. Pierce and Ilke Van Beveren for their help with concording CN8 over time.

†London School of Economics and Political Science, Grantham Research Institute on Climate Change and the Environment, S.Batrakova[at]lse.ac.uk

‡London School of Economics and Political Science, Grantham Research Institute on Climate Change and the Environment, and Centre for Economic Performance, A.Dechezlepretre[at]lse.ac.uk

1 Introduction

A major political debate is taking place in Europe and elsewhere over the pertinence of introducing carbon-based tariffs as a way to mitigate the 'leakage' of carbon to countries that do not take action against climate change. In a free-trade world, increasing carbon prices following adoption of unilateral climate policies may generate a pollution-haven effect in other countries or regions, whereby foreign countries specialise in the production of carbon-intensive products in which they have a newly acquired competitive advantage and which they can subsequently export back to 'virtuous' countries. Multinational companies may also decide to relocate their 'dirty' production activities to lower-regulated countries and export 'dirty' goods to more environmentally-friendly regions. Environmental policies may thus fail to achieve their desired objective while destroying jobs in 'greener' countries. Recent empirical papers show evidence of leakage, although this effect seems small (Levinson and Taylor (2008)). For example, Aldy and Pizer (2011) show that an increase in energy prices in the US following the introduction of a 15$/ton carbon tax would induce a domestic production decline of between 3 and 4 percent among energy-intensive sectors and a roughly 1 percent increase in imports.

By imposing a price on carbon emissions, climate change policies do not only provide incentives for companies to import carbon-intensive products from lower-regulated countries. They also encourage companies to develop new technologies that reduce the emissions intensity of their output. It has been empirically demonstrated that higher energy prices induce innovation in energy-efficient technologies (Newell et al. (1999), Popp (2002)). The potential for green policies to induce technological change has been articulated many times by policy makers, who envisage environmental policies to create domestic leadership in clean technologies.

In this paper, we examine for the first time the interaction between 'clean' innovation and 'dirty' imports. We argue that trade with lower-regulated countries might decrease firms' incentives to conduct environmentally-friendly innovation. Having been relying on imports from countries where input prices are lower, firms might be less likely to develop new technologies that use less material or energy, because cheaper inputs reduce the marginal benefit of innovation. This suggests that imports from 'dirty' countries could substitute for 'clean' innovation. In order to investigate this effect, we combine self-reported innovation data from the Community Innovation Survey with detailed firm- and product-level trade data for a sample of nearly 400 Irish companies. Ireland's highly trade-intensive economy and detailed firm-level product-level trade data make it an ideal country to investigate our research question. We use product classification information to identify carbon-intensive products and use information on the country of origin of imports to calculate the share of imports coming from lower-regulation countries. Firm-level data allows us to control for (observed) firm heterogeneity, in particular whether the firm is also an exporter, is active in non-environmental innovation, and is owned by a multinational company. We use sector fixed effects to take unobserved differences between sectors into account.

We find strong evidence that a higher proportion of 'dirty' imports sourced from BRIC countries (Brazil, Russia, India, China) has a negative impact on firms' propensity to introduce an environmental innovation. This finding is stable across various definitions of what is considered an environmental innovation and to the way we define 'dirty' imports. The magnitude of the effect is large: at the sample mean, an increase in the import share of 'dirty' products from BRIC countries in total 'dirty' imports of a firm by one standard deviation (a move from 2% to 14%) is predicted to decrease firms' propensity to introduce an environmental innovation by 5 to 8 percentage points. To put this figure into perspective, consider that the share of US imports of manufacturing goods coming from China has gone from 1.9% in 1990 to 12.1% in 2010. Thus, our results suggest that, ceteris paribus, trade with lower-regulation countries might have significantly reduced environmental innovation during the past 20 years.[1]

This paper has important policy implications. First, it suggests that leakage may not only affect jobs and emissions in the short run. It also affects long-run emissions and competitiveness by reducing incentives for firms to conduct innovation in 'clean' technologies. This may provide further justification for policies to prevent 'leakage' such as border-tax adjustment. Second, our findings suggest that importing companies are less likely to respond to environmental policies by developing 'clean' technologies. These companies may thus require stronger incentives, for example in the form of higher R&D tax credits.

This study is a substantial departure from the previous empirical literature on trade and technology, which uses country or sector-level data and mostly focuses on the role of trade for technology diffusion (Eaton and Kortum (2002); Bernard et al. (2003)) and on the impact of competition from imports on innovation (see Bloom et al. (2011)).[2] Our approach is different in that we look at the effect of firms' imports on their own innovative activity. To the best of our knowledge, the only paper that uses this approach is by Bøler et al. (2012), who examine the interdependence of R&D and intermediate inputs and their joint impact on firm productivity. Bøler et al. (2012) find that importing increases productivity, which frees up resources that are then used to increase innovation

[1]Evidence suggests that, on the other side, competition from Chinese imports may have stimulated technical change in Europe (Bloom et al. (2011)).

[2]The theoretical literature on trade and technology is well developed and has been growing constantly since the seminal paper by Grossman and Helpman (1991).

activity. In this paper, we show that when focusing on carbon-intensive imports and on environmentally-friendly innovation, the effect might well go in the opposite direction.

The paper also relates to the vast literature on the determinants of environmental innovation (see for example Horbach (2008) and Frondel et al. (2008)). Most of the recent literature has focused on the impact of environmental policy on innovation, see e.g. Newell et al. (1999), Popp (2002), Brunnermeier and Cohen (2003) and Johnstone et al. (2010). No study has yet looked at imports from 'dirty' countries as a determinant of (and a substitute for) 'clean' innovation.

The paper proceeds as follows. Section 2 develops some theoretical expectations of why 'dirty' imports may substitute for 'clean' innovation and presents our empirical strategy. Section 3 describes our data set. We present the empirical results in section 4. Some extensions and robustness tests are contained in section 5. Section 6 concludes.

2 Empirical Strategy

The objective of this paper is to analyse the link between imports of 'dirty' goods from lower-regulation countries and innovation in cleaner technologies. Economic theory can guide us in predicting how importing cheaper 'dirty' inputs can affect innovation activity in 'clean' technologies. The basic intuition is as follows.

Following Glass and Saggi (2001), consider a simple North-South product cycle model with international outsourcing where Northern firms can import intermediate goods from the South and produce the final goods in the North before selling them on world markets. A Northern firm's problem can be broken down into two stages. First, the firm chooses where to supply its intermediate goods from. It can supply them either from another Northern company or from a supplier in the South. Intermediate goods in the South are cheaper, because of lower prices of inputs (including energy). Lower energy prices may in particular stem from laxer climate regulation in the South. Crucially, this makes Southern inputs dirtier compared to inputs produced in the North, because they are more energy-intensive. Northern firms must spend resources locating a suitable supplier in the South.[3]

Once the intermediate goods have been supplied the firm then decides whether to develop a 'cleaner' technology that uses less material per unit of output, given the prices of inputs and outputs. Innovating implies paying a fixed cost related to R&D expenditures.

[3]The presence of fixed costs explains why we do not expect all firms to resort to importing despite the lower prices. See Vogel and Wagner (2010), Kasahara and Lapham (2008), Andersson et al. (2008) or Castellani et al. (2010).

It is then easy to see that firms which have chosen to import intermediate goods from the South will be less likely to innovate in the next period for two reasons. First, firms that import intermediate goods have a lower marginal cost of production, which decreases the marginal benefit of innovation. Since the cost of R&D is fixed, firms that import from the South have less to gain from developing a new input-saving technology. Second, importing is a persistent economic activity because of the sunk costs associated with finding a reliable supplier, establishing the quality of the goods, etc. Hence, importers are likely to keep on importing instead of substituting this activity with R&D which also involves significant sunk costs. The consequence of what precedes is that importing inputs from the South will have a negative impact on innovation activity directed at reducing input use.[4]

In this paper we empirically test this intuition. Our empirical method uses a probit model to estimate a firm's propensity to introduce an environmental innovation at time t conditional on past firm level covariates, as in Wooldridge (2002):

$$P(Y_{it} = 1|X_{it-1}) = G(X_{it-1}\beta) \tag{2.1}$$

where Y equals 1 if a firm introduces an environmental innovation at time t and 0 if it does not and X_{it-1} is a set of covariates that are described below. In practice we only have information on innovations introduced in the years 2006-2008 so we set $t = \{2006\}$. We use various time periods for the right-hand side variables but in our main estimations the X_{it-1} are averaged over the period 2000-2005.

More specifically, we estimate:

$$EnvInnov_{it} = \alpha ImportShare_{it-1} + \beta X_{it-1} + \delta_j + \epsilon_{it} \tag{2.2}$$

We define EnvInnov in a variety of ways that are described in full detail in Section 3 or table 9 in Appendix A. It indicates whether firm i has reported having introduced any environmental innovation or a specific innovation to reduce energy use per output or material use.

Our main variable of interest is a share of 'dirty' imports from BRIC (Brazil, Russia, India, China) countries in total 'dirty' imports of a firm, which proxies the firm's reliance on Southern suppliers for its energy-intensive inputs.[5] We check in Section 5 that our

[4] Bøler et al. (2012) find an opposite effect but their study is a more general analysis of a relationship between firms' investment in knowledge and firms' imports of intermediate goods.

[5] See section 3.2 for the definition of 'dirty' products.

results are robust to using various country groups, import shares and to the way we define 'dirty' products.[6]

We include a number of firm level controls X that include overall innovativeness, productivity, energy intensity, ownership, exporting status and size. Additionally we introduce industry controls at 2-digit level of NACE. Section 3 provides greater detail on the data and the variables used in the estimations.

One of the main issues we face in our empirical investigation is the simultaneity issue. On the one hand, we expect that importing a larger share of 'dirty' inputs from lower regulation countries might have a negative impact on the probability that a firm introduces an environmental innovation. On the other hand, input-reducing innovation might symmetrically reduce the incentive for firms to source inputs from these countries. We address the simultaneity issue in two ways. First, in order to make sure that the computed import shares are a (weakly) exogenous source of variation across firms, the shares are calculated as averages from the period of 2000-2005 while data on environmental innovation are from 2006. We thus look at how the lagged share of 'dirty' imports affects the current propensity to carry out a 'clean' innovation. All other controls (except for firms' general innovativeness) are treated the same way - we take an average of the firm values for the period 2000-2005. Second, we directly test for reverse causality by looking at whether carrying out an environmental innovation affects firm's importing behaviour from Southern countries (see Section 5.2).

Note that we do not have information on total input consumption, but only on total imports by a firm. This feature of the data is an advantage since we look only at companies that have incurred the sunk cost of importing. Importing firms might differ systematically from non-importing firms. In particular, firms that do not import at all might have more financial capabilities available to pay for the fixed cost of innovation. Moreover, Ireland is a small, open economy where inputs have to be sourced from foreign countries. Hence total imports can be seen as a good approximation of total supplies.

[6] Why not use directly the average input prices paid by firms? First, there is an obvious data constraint: input prices are a private information and collecting it for all the companies in our sample would be impossible. Second, we can reasonably assume that average input prices are negatively correlated with the share of inputs sourced from low regulation countries, and we check this on energy prices. IEA data show that Non-OECD countries have consistently had electricity prices between two and three times cheaper than OECD countries since the end of the 1970s.

3 Data

Our data are a composite of three data sets on Irish manufacturing firms. Firm level information (such as turnover, capital, etc.) comes from the Irish Census on manufacturing firms (CIP). International trade data are provided by the Irish Customs authorities. Finally, data on environmental innovation come from the 2006-2008 wave of the Community Innovation Survey. Below we describe each of the data sets in turn.

3.1 Community Innovation Survey (CIS) data

Our set of dependent variables comes from the Community Innovation Survey (CIS). The CIS data set contains survey data and covers only a proportion of the population of Irish firms present in our other data sets described below. The CIS asks Irish firms about their activity in terms of product and process innovation, R&D, cooperative behaviour in research and innovation alliances over the last three years before the survey. The wave covering the years 2006 to 2008 includes a set of questions on environmental innovation. The survey asks whether a firm has, during the last three years (2006-2008), introduced an environmental innovation that has affected its production process (such as reducing energy or material use per unit of output, reducing CO_2 footprint, air, soil, water or other pollution, etc.) or an environmental innovation that has affected a good or a service the firm produces/provides, therefore translating to an environmental benefit for an end-user. In the automobile industry, a process innovation would make the production of cars cleaner while a product innovation would result in cleaner cars (for example cars that consume less fuel or emit less local pollutants).

We use the CIS data to construct our dependent variables. We define an 'any environmental innovation on production side' dummy variable that takes on a value of 1 if a firm answered yes to any of the questions that pertain to environmental innovations on the production side of the firm's manufacturing process, and 0 otherwise.[7] We further distinguish between innovations that reduce either energy use per output or material use per unit of output and innovations that reduce any of the two separately. Finally, we also look at innovations that reduce firm's CO_2 footprint. As a robustness check, we look at innovations that improve on material use - reduce material use per output or replace

[7] CIS provides no information on firms' actual spending on an environmental innovation. It is very likely that in response to 'dirty' imports increase a firm might adjust more on the intensive rather than the extensive margin, cutting down innovation expenses but keeping an environmental innovation going. E.g. Behrens et al. (2010) finds that firms respond more at the intensive margin to the economy contraction, rather than the extensive one. Due to data limitations we are unable to observe such adjustments. If firms are likely to adjust more on the intensive margin, however, our estimates provided in section 4 should be seen as lower bounds.

materials with less polluting or hazardous substitutes, and at innovations that reduce local pollutants.

It is important to note that firms do not report their motivation behind introducing what we term a 'green' innovation. Their motives could be purely those of improving the efficiency of their own production process, having nothing to do with aspiring to be seen as more environmentally friendly and compliant. However, we argue that irrespective of firms' motivation the end result of their innovation does have environmental benefits and that is why the CIS has qualified this sub-set of innovations as environmental innovation and that is the terminology we adopt and use.

Importantly, the CIS survey is not focused on environmental innovation. We can thus use information on firms' non-environmental innovative activity to control for the propensity of firms to engage in any innovation at all. We construct a 'product/process innovations' variable that switches on when a firm reports having introduced either a product/service or a process innovation. This allows us to control for how innovative a firm is in general.

3.2 International trade data

International trade data are collected by the Irish customs authorities and provided to the Irish Central Statistics Office to match into other data sets. The data include firm-level information on imported products, including information on the country of origin. International trade data contain information on all Irish firms involved in exporting or importing activities and reporting their transactions to the customs authorities.[8] This data set includes information on the country of origin of imported products and on the country of destination of exported products, value and quantity (in tonnes), product classification at CN8 level (8-digit level of Combined Nomenclature classification) and, where available, corresponding Prodcom code.[9] The international trade data are available for a period of 2000-2009.

To construct our variable of interest in this analysis we use product codes, transaction value and country of origin of import information. We use Prodcom codes to map

[8]Only transactions above certain thresholds are reported to customs as far as within-European Union trade is concerned. More precisely only imports from EU countries in excess of €191,000 and exports to EU countries in excess of €635,000 are reported to customs. All extra-EU trade transactions have to be reported.

[9]Classification of CN8 codes changes over time with small adjustments year on year and big CN8 code overhauls in 2002 and 2007. The changes in codes over time are not always one-to-one: some codes are split into several and several old codes may be aggregated into one. Therefore, to account for and concord those classification changes over time we follow closely the methodology developed by Pierce and Schott (forthcoming) and further elaborated by Van Beveren et al. (2011). Source programmes used courtesy of Justin R. Pierce and Ilke Van Beveren.

products into a 2-digit NACE classification. We use this mapping to identify products traded in the following energy-intensive industrial sectors covered by the EU ETS (European Union Emissions Trading System): pulp and paper; coke, refined petroleum and nuclear fuel; non-metallic products; basic metals; fabricated metal products (except for machinery and equipment). We tag those products as 'dirty' for the purpose of this analysis. We then identify certain regions of the world with laxer environmental standards. Specifically, we focus on two groups - BRIC (Brazil, Russia, India, China) countries and non-OECD countries (developing world). We then combine this product information and import origin to identify 'dirty' products from 'dirty' origins to construct our main explanatory variable: a firm's share of 'dirty' imports from Southern countries in its total 'dirty' imports. This variable is defined as the value of 'dirty' products imported from BRIC or non-OECD (depending on the estimation) divided by the value of total 'dirty' imports of a firm in a given year. Multiplying this by 100 we obtain a percentage share of 'dirty' imports from a specific 'dirty' region (BRIC or non-OECD). We expect this variable to negatively affect firm's propensity to introduce an environmental, or 'clean', innovation.

We also use the trade data set to construct an exporter dummy which equals 1 if a firm is reporting exports in a given year and 0 otherwise.

3.3 CIP data

We match the trade dataset with other firm level data sets. The matching of international trade data with firm data was performed by statisticians at the Central Statistics Office Ireland (CSO). Most of the trading firms in the Census of Industrial Production data set (see below) are found in the international trade data set.[10]

The source of firm level data on manufacturing firms is the Irish Census of Industrial Production (CIP) - an annual census of manufacturing, mining and utilities firms. The Census is conducted by the Central Statistics Office (CSO) at both enterprise (firm) and plant level.[11] The CIP covers all firms or plants that employ at least 3 people. Data are available from 1991 until 2009. The CIP data set on manufacturing firms provides an unbalanced panel covering over 10,000 firms for a maximum of 19 years. The main variables available are primary industry classification (at 2-4 digit NACE level), country of

[10]The quality of matching is somewhat diminished for very big firms with turnover exceeding €5 bln. This is due to the fact that two data sets use different identifiers - a firm's id in the CIP and VAT number for the international trade data set and the mapping of the two is not very clear-cut for very big companies in the data sets. For the main analysis those firms are left in the data set but their exclusion does not alter any of our conclusions.

[11]For more information on this and other data sets described here, see the web-site of the Central Statistics Office Ireland at http://www.cso.ie/.

ownership, total turnover, export share (as a % of turnover exported), employment (measured as total employed), skill level, total labour costs, total gross earnings, outsourced R&D expenses, capital flows and energy expenditure.[12]

We use the CIP data set to control for observed firm level characteristics. Firstly, we account for firms' productivity in two ways. We control for firm's labour productivity, measured as a total turnover per employee per firm-year. To the labour productivity measure we add a control for capital. There are no data on capital stock in the CIP but there is information on capital flows, which we use to construct a proxy of capital stock measured as the discounted sum of a firm's capital flows minus sales of capital assets over the whole period. We assume a 10% annual depreciation rate. Secondly, foreign firms could be more likely to engage in innovative activity. Therefore, we control for firms' ownership status by way of a dummy variable taking on a value of 1 if a firm is foreign-owned and 0 if it is domestically-owned. Thirdly, since larger firms may have more resources available to engage in innovative activities, we include total employment in order to control for firm size.[13] Fourthly, since firms' energy dependency might well be an important factor in their decision to get involved in innovative activity that brings environmental benefits, we control for firms' energy intensity by including the (log) value of total energy expenditure per total output of a firm per year. Finally, in order to control for unobserved differences between sectors we include sector fixed effects at NACE 2-digit level. The list of sectors used in the study is given in Table 8 in Appendix A.[14]

3.4 Estimation sample and descriptive statistics

Our estimation sample is the intersection of the three datasets described above. This represents between 381 to 368 companies, depending on estimation. As most companies surveyed by the CIS are also present in the trade data set, the limiting factor is the presence in the CIS dataset.

Table 9 in Appendix A presents a full list of variables used in this analysis and their definitions. Table 10 in Appendix A provides summary statistics of the main variables[15].

[12]Monetary values are deflated using Industrial Producer Price Indices with year 2005 as a base, provided by the CSO. Energy variables are deflated using the CSO Wholesale Price Indices for Energy Products with year 2005 as a base.

[13]Note that capital and employment figures were divided by 1000 to bring estimation coefficients into a more measurable magnitude. Summary statistics are given in reported magnitudes.

[14]CIP uses NACE Revision 1.1 up to 2007. NACE 1.1 is a European statistical classification system of economic activities corresponding to ISIC Rev.3 at European level. From 2008 onwards CIP uses NACE Revision 2 classification which was re-classified back to Revision 1.1. using correspondence tables provided by Eurostat.

[15]Any negative or missing values of main firm level variables in few instances where possible were replaced using values from previous and later years, the rest - set to missing.

74% of companies report having carried out some innovation on the process or production side. Interestingly, 66% report having carried out production side environmental innovation. 43% of companies have innovated in order to reduce energy use per output, 38% in order to reduce material use per output and 50% have reported introducing either innovation. 49% of firms introduced CO_2 reducing innovation.

4 Importing and innovation

This Section presents the outcomes of our main estimations. As our econometric model is nonlinear we then interpret our findings and discuss the magnitudes of the effects.

4.1 Main results

Table 1 presents our main results. We investigate the impact of firm's (lagged) share of 'dirty' imports from BRIC countries (Brazil, Russia, India, China) in all 'dirty' imports on its propensity to introduce an environmental innovation (see equation 2.2). In column 1 the dependent variable is an environmental innovation reducing either material or energy use per output, a variable representing the closest substitute to a share of intermediate 'dirty' imports of a firm. In column 2 we look at outcomes for environmental innovation reducing energy use per output and in column 3 - at outcomes for environmental innovation reducing material use per output, column 4 shows an estimation for CO_2 reducing environmental innovation and finally column 5 details the results for a more general innovation variable - any environmental innovation on production side - any kind of innovation that brings environmental benefits to the production side of a firm.[16]

We find that the share of products imported from BRIC countries in the 'dirty' imports of a firm has a negative and significant effect on the probability that a firm reports an environmental innovation. This suggests that if a firm has been relying relatively more on imports from developing countries in the period up to 2005, it has fewer incentives and, perhaps, fewer resources in the following period to engage in innovative activity that brings environmental benefits. It is likely that cheaper inputs make the prospect of paying out a fixed cost to engage in input-reducing innovation less attractive as the marginal benefits of reducing material or energy use would be smaller for import reliant firms. This finding is robust across various definitions of environmental innovation. The point

[16] See Section 3 or table 9 in Appendix A for a detailed description of various dependent variables.

Table 1: Share of 'dirty' imports and propensity to carry out environmental innovation

	Innovation reducing material or energy use per output	Innovation reducing energy use per output	Innovation reducing material use per output	Innovation reducing CO_2	Any environmental innovation on production side
Share of 'dirty' imports from BRIC in all 'dirty' imports	-0.0169***	-0.0116**	-0.0121**	-0.0140***	-0.0143***
	(0.0051)	(0.0050)	(0.0055)	(0.0052)	(0.0047)
Product/process innovations	1.7212***	1.6644***	1.3201***	1.3353***	1.8006***
	(0.2119)	(0.2238)	(0.2108)	(0.2036)	(0.1918)
Exporter	0.4454*	0.2935	0.5630**	0.0283	0.1650
	(0.2343)	(0.2424)	(0.2442)	(0.2308)	(0.2251)
Log labour productivity	0.1614	0.2180*	0.2205*	0.3176**	0.0001
	(0.1276)	(0.1302)	(0.1194)	(0.1244)	(0.1280)
Capital	0.0066	0.0063	-0.0007	-0.0017	0.0151*
	(0.0075)	(0.0065)	(0.0037)	(0.0037)	(0.0083)
Log energy intensity	3.1537	3.5457	2.8731	0.4222	-6.6660
	(3.7035)	(3.5054)	(4.0385)	(3.8018)	(4.0617)
Size	0.7577*	0.7120	0.6539*	0.3740	0.1662
	(0.4565)	(0.4628)	(0.3906)	(0.3729)	(0.4753)
Ownership	-0.1331	0.0684	-0.1210	0.4253**	0.0413
	(0.1892)	(0.1918)	(0.1844)	(0.1939)	(0.2084)
Number of firms/observations	376	370	368	368	381

Robust standard errors in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
The dependent variable is the propensity to introduce an innovation as stated above.
All columns include 2 digit industry dummies and a constant (not reported).
All columns estimated by probit.

estimate is highest (in absolute terms) when we use 'environmental innovation reducing material or energy use per output' as a dependent variable, which is in line with our expectation of it being the closest substitute for the type of inputs used to construct our explanatory variable.[17] There is therefore a direct trade-off between importing those inputs cheaply or trying to reduce their use by way of introducing a new technology.

Unsurprisingly, we find that a firm's overall innovativeness which we measure as its engagement in any product or process innovation is an important predictor of a firm's propensity to introduce an environmental innovation. This variable always has a positive and significant effect on firms' probability of reporting a 'green' innovation. Importantly, the ownership variable is not statistically significant in most estimations, suggesting that the importing behaviour of companies owned by a multinational does not differ systematically from that of domestically-owned companies.

As for other controls, more productive firms are more likely to introduce environmental innovation in 3 out of 5 base estimations and being an exporters seems, in some cases, to have a positive effect too.

[17]Because companies do not reply to all questions in the CIS survey, the sample size decreases slightly as we change the dependent variable. However the results remain very similar when we re-run all columns on the smaller sample used in column (3).

Table 2: Share of 'dirty' imports and propensity to carry out environmental innovation, marginal effects

	Innovation reducing material or energy use per output	Innovation reducing energy use per output	Innovation reducing material use per output	Innovation reducing CO_2	Any environmental innovation on production side
Share of 'dirty' imports from BRIC in all 'dirty' imports	-0.0067***	-0.0045**	-0.0045**	-0.0051***	-0.005***
	(0.0020)	(0.0019)	(0.0020)	(0.0019)	(0.0016)
Product/process innovations	0.564***	0.5039***	0.3977***	0.4***	0.6298***
	(0.0460)	(0.0435)	(0.0457)	(0.0445)	(0.0530)
Exporter	0.1775*	0.1132	0.2079**	0.0104	0.0574
	(0.0933)	(0.0933)	(0.0893)	(0.0851)	(0.0781)
Log labour productivity	0.0643	0.0841*	0.0815*	0.1171**	0.00003
	(0.0508)	(0.0503)	(0.0443)	(0.0459)	(0.0445)
Capital	0.0026	0.0024	-0.0002	-0.0006	0.0053*
	(0.0030)	(0.0025)	(0.0014)	(0.0013)	(0.0029)
Log energy intensity	1.2569	1.3674	1.061	0.1556	-2.3183
	(1.4760)	(1.3501)	(1.4923)	(1.4014)	(1.3997)
Size	0.302*	0.2746	0.2415*	0.1379	0.0578
	(0.1819)	(0.1786)	(0.1448)	(0.1377)	(0.1654)
Ownership	-0.0531	0.0264	-0.0447	0.1568**	0.0144
	(0.0754)	(0.0740)	(0.0681)	(0.0715)	(0.0725)
Number of firms/observations	376	370	368	368	381

Robust standard errors in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
The dependent variable is the propensity to introduce an innovation as stated above.
All columns include 2 digit industry dummies and a constant (not reported).
All columns estimated by dprobit.

4.2 Magnitudes

The nonlinear nature of probit models does not allow us to interpret the coefficients in table 1 straight away. Table 2 presents the results in terms of marginal effects. We find that the effect of import on innovation is large: a one percentage point increase in the share of 'dirty' inputs sourced from Southern countries leads to a decrease in the probability of innovating by 0.45 to 0.67 percentage points.

In order to assign some economic significance to the magnitudes of the effect of interest, we calculate the change in the predicted outcome probability in two scenarios - an increase of imports share of 'dirty' products from BRIC countries in total 'dirty' imports of a firm by 1 standard deviation from the sample mean and a more prominent increase of this imports share from 25% to 50%. Results are reported in table 3.

The mean value of the 'dirty' imports share is not very high in our data (around 2%). This is due to the large number of zeros in the data set. There is, however, a substantial heterogeneity amongst firms in their importing behaviour and the standard deviation is therefore quite high. A one standard deviation increase entails a move from 2% to 14% of 'dirty' imports share from BRIC countries. Such an increase is predicted to decrease firms' propensity to introduce an environmental innovation by a range of 5 to 8 percentage points depending on the kind of environmental innovation. To put this figure into perspective, consider that the share of Chinese imports in the USA's imports of manufacturing goods has gone from 1.9% in 1990 to 12.1% in 2010. This suggests that, all else being equal, trade with BRIC countries might have significantly reduced environmental innovation during the past 20 years.

The impact of imports varies slightly across the types of innovation. Again, we find the highest impact when we look at the likelihood of material- or energy-saving innovation, which decreases by 8 percentage points. The decrease in the probability of a firm to introduce a production-side environmental innovation is of 6 percentage points, the same value is attained for a probability of introducing a CO_2 reducing innovation. The probability to introduce either an energy-saving or a material-saving innovation goes down by 5 percentage points.

When we consider an increase in 'dirty' imports share from 25% to 50% the estimated decrease in the probability of innovation varies between 14 and 9 percentage points depending on the type of innovation considered and seems to be higher for more general types of innovation (production side or energy and material reducing), rather than innovation tackling a reduction of one specific factor or outcome. These figures illustrate the non-linear nature of the impact. The marginal impact of a higher reliance on Southern imports decreases as this reliance grows, possibly because the impact of the fixed cost of selecting the appropriate supplier is highest at low values of import reliance.

Table 3: Quantification of the results

	Innovation reducing material or energy use per output	Innovation reducing energy use per output	Innovation reducing material use per output	Innovation reducing CO_2	Any environmental innovation on production side
1 standard deviation increase in imports of 'dirty' goods from BRIC reduces propensity to innovate by	**8pp**	**5pp**	**5pp**	**6pp**	**6pp**
25% to 50% increase in imports of 'dirty' goods from BRIC reduces propensity to innovate by	**14pp**	**9pp**	**9pp**	**9pp**	**14pp**

Derived after probit estimations in tables above. Response given in percentage point changes (pp).

In summary, our results offer strong support for our theory. Firms that are more reliant on 'dirty' imports from the developing world are significantly less likely to engage in environmental (energy- and material-saving) innovation. This suggests that there is a certain path dependency in firms' innovative activity depending on their trade history.

5 Robustness Checks

We have performed a number of robustness checks to corroborate the main results reported in Section 4 and we describe them here.[18] As we have identified environmental innovation reducing either material or energy use per output as the closest substitute for firm's imported inputs that we use as our explanatory variable of interest, we report all the checks using this type of environmental innovation.

5.1 Endogeneity and unobserved heterogeneity

We are concerned about the endogeneity of the general innovativeness of firms as proxied by the 'Product/process innovation' control variable. Indeed some unobserved factors that influence general innovativeness may also influence our dependent variable. To address this issue, we restrict the sample to innovating firms only - i.e. those firms that reported having introduced at least one product or process innovation - and drop the endogenous variable. The results are reported in column 1 of table 4. Our results hold very well for this restricted sample and we still show a negative and strongly significant effect of the import share of 'dirty' goods from BRIC countries on the propensity to introduce an environmental innovation. In column 2 of the same table we also drop the overall innovativeness of a firm variable and the result holds too.

We have also re-run all the estimations and checks reported in the paper on this smaller sub-sample of only innovating firms and all the results are qualitatively the same which shows that none of our findings are driven by some unobserved differences between innovating and not innovating firms. This helps alleviate one of the main concerns of unobserved heterogeneity between firms since the cross-sectional nature of our data does not allow to perfectly control for it. We try to control for as much observed heterogeneity as we can using many firm-level control variables. Additionally, we repeat our estimations with industry controls at 3- and 4-digit levels to account for any possible industry-specific credit constraints that may prevent firms in the affected industries from getting funding necessary to import or engage in innovation. All our results are unaffected by these finer levels of industry controls.

We then check that the pattern of our findings is not due to some spurious correlation or due to a part of some general trend. Firstly, we estimate the impact of Southern imports on total innovation activity (i.e., any product or process innovation) and specifically on non-environmental innovation (see respectively columns 3 and 4 of table 4). We find that a share of 'dirty' imports from BRIC in total 'dirty' imports of a firm has no effect on

[18] Not all output tables are shown here for reasons of parsimony but all are available on request.

total innovativeness of a firm and has a positive effect on non-environmental innovation. In other words the share of 'dirty' imports from BRIC has a negative effect only on environmental innovation. Secondly, we look at the impact of the share of 'clean' imports from BRIC in total imports - compared to our previous explanatory variable, we now look at non-'dirty' imported products instead of focusing on 'dirty' (highly energy-intensive) products. Results are reported in column 5 of table 4. We find that the share of 'clean' imports from BRIC countries does not have any impact on environmental innovation. This suggests that we find an effect only where you would expect it, i.e. when looking at energy-intensive products.[19]

Table 4: Share of 'dirty' imports and propensity to carry out various innovations, marginal effects

	Only innovating firms[1]	No control for innovativeness[1]	Effect on any product/process innovation[2]	Effect on non-environmental innovation[3]	Share of 'clean' imports from BRIC[1]
Share of 'dirty' imports from BRIC in all 'dirty' imports	-0.0061***	-0.0044**	0.0038	0.0048***	
	(0.0019)	(0.0020)	(0.0028)	(0.0014)	
Share of 'clean' imports from BRIC in total firms' imports					0.0012
					(0.0020)
Product/process innovations					0.5361***
					(0.0396)
Exporter	0.2127**	0.2228***	0.1266*	-0.0378	0.1836**
	(0.0974)	(0.0852)	(0.0654)	(0.0645)	(0.0766)
Log labour productivity	0.0533	0.0556	-0.0053	-0.008	0.0499
	(0.0527)	(0.0444)	(0.0397)	(0.0387)	(0.0428)
Capital	0.0026	0.0024	0.0005	-0.0049	0.003
	(0.0031)	(0.0025)	(0.0013)	(0.0029)	(0.0032)
Log energy intensity	1.6815	0.2338	-1.0162	1.3338	1.7105
	(2.0687)	(1.4147)	(1.1344)	(1.9470)	(1.2586)
Size	0.3329*	0.3946**	0.3271*	-0.0999	0.3189*
	(0.1879)	(0.1755)	(0.1654)	(0.1399)	(0.1824)
Ownership	-0.0654	-0.0569	-0.0574	0.033	-0.0123
	(0.0795)	(0.0731)	(0.0602)	(0.0583)	(0.0702)
Number of firms/observations	276	376	371	256	458

Robust standard errors in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
[1] The dependent variable is the propensity to introduce innovation reducing material or energy use per output.
[2] The dependent variable is the propensity to introduce any product or process innovation.
[3] The dependent variable is the propensity to introduce non-environmental product or process innovation.
All columns includes 2 digit industry dummies and a constant (not reported).
All columns estimated by dprobit.

5.2 Reverse causality

Another important source of concern is the potential issue of reverse causality. Having already introduced an environmental innovation may decrease firms' share of 'dirty' imports, or the decisions to engage in 'clean' innovation activities and to reduce the imports of 'dirty' products might be taken simultaneously.

[19]The same result holds when looking at the share of all imports from BRIC in total imports of a firm.

As explained above we try to address the simultaneity concerns by estimating the effect of 'dirty' imports shares averaged over the period 2000-2005 on environmental innovation decision the following year - 2006.

Here we check whether environmental innovation directly affects 'dirty' imports. We construct a variable which represents a difference between firm's import shares of 'dirty' products from BRIC countries in 2009 and the same import shares pre-2006. It allows us to examine if a firm's involvement in environmental innovations has affected its subsequent importing behaviour. Results are reported in table 5. We find that firms' 'clean' innovation activity does not significantly change their importing behaviour in the years following the introduction of a cleaner technology, compared to the years before this introduction. First-differencing also allows controlling for firm fixed effects.

Table 5: Effect of environmental innovations on a difference in share of 'dirty' imports

Environmental innovation reducing material or energy use per output	0.2217				
	(2.043)				
Environmental innovation reducing energy use per output		-0.988			
		(2.007)			
Environmental innovation reducing material use per output			2.4273		
			(2.351)		
Environmental innovation reducing CO_2				0.9108	
				(2.226)	
Any environmental innovation on production side					1.7604
					(2.369)
Product/process innovations	0.6038	1.3947	2.0102	0.7183	1.2275
	(2.085)	(1.747)	(1.764)	(1.596)	(1.584)
Exporter	-0.1022	0.0448	0.2696	-0.4706	0.0836
	(3.746)	(3.927)	(3.892)	(4.002)	(3.794)
Difference in log labour productivity	1.5103	1.6408	1.618	1.5942	1.5579
	(2.327)	(2.266)	(2.350)	(2.357)	(2.380)
Difference in capital	0.0078	0.009	0.0119	0.0016	0.0071
	(0.022)	(0.024)	(0.024)	(0.026)	(0.025)
Difference in log energy intensity	-14.6111	-9.2008	-8.2682	-14.1354	-13.0563
	(55.705)	(56.563)	(56.633)	(57.911)	(58.304)
Difference in size	10.0106	9.9088	9.7441	10.5971	9.787
	(7.434)	(7.414)	(7.399)	(7.571)	(7.606)
Ownership	-0.7599	-0.722	-0.6171	-0.7808	-0.9339
	(2.946)	(2.933)	(2.928)	(2.924)	(2.967)
Number of firms/observations	300	300	295	295	293
R-squared	0.083	0.081	0.082	0.086	0.082

Robust standard errors in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
The model includes 2 digit industry dummies and a constant (not reported).
Dependent variable: 2009 and pre-2006 mean difference in import share of 'dirty' products from BRIC countries in all 'dirty' imports. All columns estimated by OLS.

Another check is to simply switch around the dependent variable and our main explanatory variable of interest. Results presented in table 6 show that although the sign of the environmental innovation variable is negative, all bar one coefficients are not statistically significant. Therefore we are fairly certain that 'green' innovation activity does not lead to lower share of 'dirty' imports in a firm.

Table 6: Effect of environmental innovations on share of 'dirty' imports

Environmental innovation reducing material or energy use per output	-4.7435*				
	(2.532)				
Environmental innovation reducing energy use per output		-3.1365			
		(2.297)			
Environmental innovation reducing material use per output			-1.877		
			(2.077)		
Environmental innovation reducing CO_2				-2.1408	
				(2.065)	
Any environmental innovation on production side					-2.0882
					(2.587)
Product/process innovations	3.2579	4.5817	3.6091	2.7592	2.8531
	(2.693)	(2.806)	(2.628)	(2.344)	(2.358)
Exporter	-1.9076	-1.4075	-1.721	-1.6431	-2.0682
	(3.159)	(3.044)	(3.097)	(3.150)	(3.158)
Log labour productivity	-1.8123	-1.5207	-1.6668	-1.6536	-1.6376
	(1.344)	(1.294)	(1.330)	(1.347)	(1.370)
Capital	-0.0063	-0.0027	-0.004	-0.0071	-0.0042
	(0.016)	(0.016)	(0.016)	(0.015)	(0.014)
Log energy intensity	-21.1623	-18.9404	-19.7268	-18.7369	-19.4151
	(50.147)	(49.937)	(50.201)	(50.008)	(50.036)
Size	3.5386	3.8414	3.7218	3.5429	3.9828
	(3.830)	(3.798)	(3.832)	(3.923)	(3.914)
Ownership	-0.9303	-0.8408	-0.4758	-0.8694	-0.4267
	(2.013)	(2.038)	(2.049)	(2.111)	(2.008)
Number of firms/observations	344	344	339	339	338
R-squared	0.075	0.085	0.079	0.075	0.077

Robust standard errors in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
The model includes 2 digit industry dummies and a constant (not reported).
Dependent variable: import share of 'dirty' products from BRIC countries in all 'dirty' imports of a firm in 2006. All columns estimated by OLS.

5.3 Other checks

Outlying observations

To make sure some outlying influential observations do not affect the pattern of our findings we have removed the top and bottom 1% of firms. All our findings remain unchanged and the coefficients are of very similar magnitudes to those reported as the main results.

Table 7: Share of 'dirty' imports and propensity to carry out any environmental innovation, selected checks, marginal effects

	Non-zero import flows	Import share in 2005 only	Effect of import share of BRIC in total imports	EU import share
Share of 'dirty' imports from BRIC in all 'dirty' imports	-0.0034*	-0.0063***		
	(0.0021)	(0.0021)		
Share of 'dirty' imports from BRIC in total firm's imports			-0.0113**	
			(0.0051)	
Share of 'dirty' imports from EU in all 'dirty' imports				0.0006
				(0.0008)
Product/process innovations		0.6067***	0.5416***	0.5547***
		(0.0484)	(0.0391)	(0.0472)
Exporter	0.4522**	0.208**	0.1714**	0.1835**
	(0.2123)	(0.0928)	(0.0764)	(0.0935)
Log labour productivity	0.1215	0.0681	0.047	0.0629
	(0.1175)	(0.0549)	(0.0429)	(0.0502)
Capital	0.011	0.0043	0.0029	0.0027
	(0.0091)	(0.0035)	(0.0031)	(0.0031)
Log energy intensity	8.186	1.4739	1.3181	1.5213
	(4.2042)	(1.7715)	(1.3024)	(1.4063)
Size	-0.0008	0.0599	0.3161*	0.3095*
	(0.4216)	(0.1807)	(0.1814)	(0.1838)
Ownership	-0.0526	0.0545	-0.0195	-0.0302
	(0.1903)	(0.0795)	(0.0706)	(0.0756)
Number of firms/observations	62	321	458	376

Robust standard errors in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
The dependent variable is the propensity to introduce environmental innovation reducing material or energy use per output, same as in column (2), table 1.
All columns includes 2 digit industry dummies and a constant (not reported).
All columns estimated by dprobit.

Alternative estimations

We have run estimations without collapsing the data set to a firm-year dimension to allow us to additionally control for country of imports origin fixed effects and product fixed effects at 2-digit level. The results remained qualitatively the same in those estimations.

The results also hold well when we focus only on firms with non-zero shares of 'dirty' imports from BRIC (see table 7, column 1).

Our results remain similar when we use the same estimation as when deriving the main results but change the share of 'dirty' imports from BRIC countries from being a value averaged over 2000-2005 period to the 2005 value (see table 7, column 2). We also find a similar pattern of outcomes when we look at (log) absolute values of 'dirty' imports from the BRIC/non-OECD instead of the share of these imports. Additionally we look at the share of imports from BRIC in total imports of a firm and find a very similar pattern of results there, see column 3 of table 7.

Other imports

China and India account for most of the BRIC imports. Unsurprisingly, then, our results are mostly driven by the share of 'dirty' imports from these two countries, and our results remain stable if we focus on imports from these two countries only.

We have also looked at imports from other regions. The share of 'dirty' imports from the OECD or from the EU in total 'dirty' imports do not have any significant effect on the propensity to introduce an environmental innovation in the next period (see table 7, column 4). Together with finding no effect of 'clean' BRIC imports share as reported in column 4 of table 4, this suggests that both origin of imports and its content are important for the probability of an environmental innovation introduction.

Our findings are not supported when we look at a share of 'dirty' imports from non-OECD in total 'dirty' imports of a firm but we do find that a higher share of 'dirty' imports from non-OECD countries in total firm's imports tends to reduce the probability to introduce an environmental innovation targeted at reducing energy or material use or both.

Cheapest suppliers

As an additional check on inputs origin country mix, in line with our theoretical motivation, we have looked at the countries from where Irish firms source the cheapest 25% of their 'dirty' inputs from. Our results using the share of 'dirty' inputs from the cheapest countries in total 'dirty' imports of a firm still point in the same direction but they are less statistically significant. However, when we remove the UK from the mix of countries of 'dirty' import origins due to old and strong economic, cultural and political ties between Ireland and the UK, that make the latter a 'special case' for the Irish economy, our results become much clearer and support the finding of prior reliance on cheap 'dirty' inputs reducing firms' propensity to engage in environmental innovation.

Other environmental innovations

We tried other definitions of environmental innovation. We find that the share of 'dirty' imports from BRIC countries significantly decreases firm's propensity to introduce innovation that either reduces material use or replaces its materials with less polluting or hazardous substitutes. We also uncover the same pattern for environmental innovations concerning local pollutants, such as innovations reducing soil, water, noise or air pollution and innovations improving recycling, both on production and on the end-user after sale side.

Over-reporting

There may be a concern pertaining to companies wishing to look more environmentally-friendly and thus over-reporting 'green' innovations. Since we find that the 'dirty' imports reduce the propensity to introduce an environmental innovation, if companies indeed over-report these innovations, then our findings would represent a lower bound of estimates.

Other controls

Controlling for the number of countries from which the import originate does not change any of the results.

6 Conclusions

Pollution haven and carbon 'leakage' are two of the main issues facing the implementation of carbon emissions reduction policies. We add to the literature on this subject by looking at the impact of trade with lower-regulated countries on firms' propensity to engage in 'clean' innovation. Firms importing 'dirty' inputs from countries where input prices are lower might be less likely to develop new technologies that use less material or energy. We test this hypothesis using a newly constructed data set that combines firm level and international trade data with self-reported innovation information from the Community Innovation Survey. Our data cover around 400 Irish companies.

We find robust evidence that a higher previous share of imports from BRIC countries (Brazil, Russia, India, China) in a firm's 'dirty' imports significantly decreases a firm's propensity to introduce an environmental innovation in the next period. This finding is stable across various definitions of 'clean' innovation and of the group of countries used to define imports from Southern countries. The magnitude of the effect is large: an increase of imports share of 'dirty' products from BRIC countries in total 'dirty' imports by one standard deviation (a move from 2% to 14%) is predicted to decrease firms' propensity to introduce an environmental innovation by 5 to 8 percentage points. To put this figure into perspective, consider that the share of Chinese imports in the USA's imports of manufacturing goods has gone from 1.9% in 1990 to 12.1% in 2010. Thus, our results suggest that trade with lower-regulation countries might have significantly reduced environmental innovation during the past 20 years. These results could be generalised to many European countries that are small open economies, e.g. Belgium.

These results have important policy implications. First, our findings suggest that importing companies are less likely to respond to environmental policies by developing 'clean' technologies. Firms who are already importing 'dirty' inputs might therefore need an additional incentive to develop 'clean' technologies in order to overcome this path dependency, for example in the form of higher R&D tax credits. Second, our paper suggests that 'leakage' may not only affect jobs and emissions in the short run. It also affects long-run competitiveness by reducing incentives for firms to conduct innovation in 'clean' technologies. This may provide further justification for policies aimed at preventing 'leakage' such as border-tax adjustment.

Our paper has a number of limitations. The most important one is that the Community Innovation Survey has introduced questions related to environmental innovation on a one-off basis, leaving us with a single wave of results to analyse. As a consequence we run cross-sectional estimations that do not allow us to perfectly control for unobserved heterogeneity. We do our best to control for observed heterogeneity by including many control variables, but this approach is obviously imperfect. We leave attempts to improve on this limitation for future research.

A Appendix

Table 8: List of NACE 2 digit industries in the Census of Industrial Production (CIP)

NACE Code	Description
15	Manufacture of food products and beverages
16	Manufacture of tobacco products
17	Manufacture of textiles
18	Manufacture of wearing apparel; dressing and dyeing of fur
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
21	Manufacture of pulp, paper and paper products
22	Publishing, printing and reproduction of recorded media
23	Manufacture of coke, refined petroleum products and nuclear fuel
24	Manufacture of chemicals and chemical products
25	Manufacture of rubber and plastic products
26	Manufacture of other non-metallic mineral products
27	Manufacture of basic metals
28	Manufacture of fabricated metal products, except machinery and equipment
29	Manufacture of machinery and equipment n.e.c.
30	Manufacture of office machinery and computers
31	Manufacture of electrical machinery and apparatus n.e.c.
32	Manufacture of radio, television and communication equipment and apparatus
33	Manufacture of medical, precision and optical instruments, watches and clocks
34	Manufacture of motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment
36	Manufacture of furniture; manufacturing n.e.c.

NACE classification followed in this study is NACE Rev 1.1 - a European statistical classification system of economic activities corresponding to ISIC Rev.3 at European level.

Table 9: Definition of variables

Variable	Description
Environmental innovation on production side	1 if a firm answered yes to any of the environmental innovations on production side - it reduced material or energy use per unit of output, reduced CO_2 footprint, replaced materials with less polluting substitutes, reduced soil, water, noise, or air pollution, recycled waste, water, or materials.
Environmental innovation reducing material or energy use per output	1 if a firm answered yes to either introducing an environmental innovation reducing material use per unit of output or energy use per unit of output.
Environmental innovation reducing energy use per output	1 if a firm answered yes to introducing an environmental innovation reducing energy use per unit of output.
Environmental innovation reducing material use per output	1 if a firm answered yes to introducing an environmental innovation reducing material use per unit of output.
Environmental innovation reducing CO_2	1 if a firm answered yes to introducing an environmental innovation reducing CO_2 footprint and 0 otherwise.
Product/process innovation	A dummy that switches on to 1 when a firm reports having introduced either a product/service or a process innovation.
Share of 'dirty' imports from BRIC	Value of 'dirty' products from Brazil, Russia, India, China in total value of firm's 'dirty' imports per year. 'Dirty' - products that correspond to the industries of pulp and paper products; coke, refined petroleum products and nuclear fuel products; non-metallic products; basic metals; fabricated metal products, with exception of machinery and equipment.
Share of 'dirty' imports from Non-OECD	Value of 'dirty' products from Non-OECD region in total value of firm's 'dirty' imports per year.
Exporter	Dummy variable equal to 1 if a firm exports in any given year and 0 otherwise.
Ownership	Dummy variable equal to 1 if a firms is foreign-owned and 0 if it is a domestic firm.
Labour Productivity	Total turnover divided by the number of employees.
Capital	Firm's capital additions built over the whole period minus sales of capitals assets, assuming 10% yearly depreciation rate overall.
Energy Intensity	Total energy expenditure per output per firm-year.
Size	Total number of people employed.

Table 10: Summary statistics

Variable	Mean	Std. Dev.	Min	Max	N
Environmental innovation on production side	0.6576	0.4752	0	1	368
Environmental innovation reducing material or energy use per output	0.5	0.5007	0	1	368
Environmental innovation reducing energy use per output	0.4305	0.4958	0	1	368
Environmental innovation reducing material use per output	0.3815	0.4864	0	1	368
Environmental innovation reducing CO_2 footprint	0.3832	0.4868	0	1	368
Any environmental innovation	0.674	0.4694	0	1	368
Product/process innovation	0.731	0.4441	0	1	368
Share 'dirty' imports from BRIC in total 'dirty' firms' imports (%)	2.4723	12.1262	0	100	368
Share 'dirty' imports from BRIC in total firms' imports (%)	1.2441	8.6555	0	100	368
Share all imports from BRIC in total firms' imports (%)	3.0472	10.824	0	100	368
Share 'dirty' imports from Non-OECD in total firms' imports (%)	1.7549	10.1573	0	100	368
Log Labour Productivity	5.0679	0.7819	2.4503	8.8845	368
Capital	6305.8	22846.2	-1380	324171.8	368
Ownership	0.3962	0.4777	0	1	368
Total Employed	155.9	265.5	7.9	2410	368
Energy expenditure	877.3558	2937.9393	1.8248	43104.9258	368
Energy Intensity	0.0214	0.0331	0.0002	0.3725	368
Total turnover (output)	52690.8311	129372.2245	420.7246	1302361	368
Log Energy Intensity	0.0207	0.023	0.0002	0.2083	368

Reported are mean values at firm level for the estimation sample of column 5, table 1.
All monetary values are in thousands of euros.

Table 11: Means comparison between firms in and outside of the CIS

Variable	Mean in the CIS	Mean outside the CIS	$t-test$ difference	
Share 'dirty' imports from BRIC in total firms' 'dirty' imports (%)	1.9134	5.8503	3.94***	(3.81)
Share 'dirty' imports from BRIC in total firms' imports (%)	0.9901	2.3418	1.35**	(2.87)
Share 'dirty' imports from Non-OECD in total firms' imports (%)	1.5315	3.6006	2.07***	(3.33)
Log Labour Productivity	4.8991	4.5711	-0.33***	(-9.83)
Capital	4381.7	775.5	-3606***	(-6.57)
Ownership	0.272	0.0731	-0.2***	(-16.30)
Total Employed	112.3	31.5	-80.8***	(-15.75)
Energy expenditure	608.4338	112.3808	-496.05***	(-7.92)
Energy Intensity	0.0222	0.0221	0.0001	(0.42)
Total turnover (output)	35542.4801	14646.0136	-20896.47***	(-5.42)
Log Energy Intensity	0.0209	0.0216	-0.0007	(-0.43)

Reported are mean values at firm level over the period of 2000-2009.
All monetary values are in thousands of euros.

Table 12: Means comparison between firms in and outside of the trade data

Variable	Mean in the trade data	Mean outside the trade data	$t-test$ difference	
Any environmental innovation	0.6215	0.3988	-0.223***	(-5.12)
Product/process innovation	0.7085	0.4286	-0.280***	(-6.73)
Environmental innovation on production side	0.6032	0.381	-0.222***	(-5.09)
Environmental innovation reducing material or energy use per output	0.4494	0.2381	-0.211***	(-4.92)
Environmental innovation reducing energy use per output	0.3914	0.1976	-0.194***	(-4.62)
Environmental innovation reducing material use per output	0.3381	0.1856	-0.152***	(-3.75)
Environmental innovation replacing materials with less polluting or hazardous substitutes	0.3217	0.2061	-0.116**	(-2.84)
Log Labour Productivity	4.9015	4.4169	-0.485***	(-20.02)
Capital	3944	399.7	-3.544***	(-4.27)
Ownership	0.2304	0.016	-0.214***	(-22.09)
Total Employed	89.4	17.5	-0.0719***	(-14.12)
Energy expenditure	475.7775	61.6721	-414.1***	(-6.06)
Energy Intensity	0.0233	0.0212	-0.00206*	(-1.98)
Total turnover (output)	48020.3437	6958.7139	-41061.6***	(-4.40)
Log Energy Intensity	0.0223	0.0211	-0.00128	(-1.59)

Reported are mean values at firm level over the period of 2000-2009.
All monetary values are in thousands of euros.

Table 13: Means comparison between firms in the CIS data set that trade and do not

Variable	Mean in the trade data	Mean outside the trade data	$t - test$ difference	
Any environmental innovation	0.6215	0.3988	-0.223***	(-5.12)
Product/process innovation	0.7085	0.4286	-0.280***	(-6.73)
Environmental innovation on production side	0.6032	0.381	-0.222***	(-5.09)
Environmental innovation reducing material or energy use per output	0.4494	0.2381	-0.211***	(-4.92)
Environmental innovation reducing energy use per output	0.3914	0.1976	-0.194***	(-4.62)
Environmental innovation reducing material use per output	0.3381	0.1856	-0.152***	(-3.75)
Environmental innovation replacing materials with less polluting or hazardous substitutes	0.3217	0.2061	-0.116**	(-2.84)
Log Labour Productivity	5.0194	4.5451	-0.474***	(-6.56)
Capital	5642.9	680.2	-4.963**	(-2.75)
Ownership	0.3472	0.0508	-0.296***	(-7.65)
Total Employed	139	33.8	-0.105***	(-5.13)
Energy expenditure	775.1395	118.2399	-656.9**	(-3.05)
Energy Intensity	0.0227	0.0206	-0.00216	(-0.69)
Total turnover (output)	45204.693	7130.9733	-38073.7***	(-3.69)
Log Energy Intensity	0.0212	0.0199	-0.00130	(-0.66)

Reported are mean values at firm level over the period of 2000-2009.
All monetary values are in thousands of euros.

Table 14: Means comparison between firms in the CIS and trade data sets that innovate 'green' or not

Variable	Mean in the trade data	Mean outside the trade data	$t - test$ difference	
Product/process innovation	0.9251	0.3529	-0.572***	(-17.10)
Share 'dirty' imports from BRIC in total firms' 'dirty' imports (%)	2.0184	3.2282	1.210	(0.92)
Share 'dirty' imports from BRIC in total firms' imports (%)	1.051	1.0712	0.0202	(0.03)
Share 'dirty' imports from Non-OECD in total firms' imports (%)	1.7349	1.4737	-0.261	(-0.28)
Log Labour Productivity	5.1059	4.8768	-0.229**	(-2.95)
Capital	7865.2	1991	-5.874**	(-2.73)
Ownership	0.3862	0.283	-0.103*	(-2.31)
Total Employed	171.2	85.8	-0.0855***	(-3.54)
Energy expenditure	1030.911	355.2365	-675.7**	(-2.63)
Energy Intensity	0.0213	0.0252	0.00389	(1.27)
Total turnover (output)	58669.3611	23099.5961	-35569.8**	(-2.90)
Log Energy Intensity	0.0214	0.0208	-0.000552	(-0.25)

Reported are mean values at firm level over the period of 2000-2009.
All monetary values are in thousands of euros.

References

Aldy, Joseph E. and William A. Pizer, "The Competitiveness Impacts of Climate Change Mitigation Policies," December 2011. NBER Working Paper No. 17705. Cambridge, MA: National Bureau of Economic Research.

Andersson, Martin, Hans Lööf, and Sara Johansson, "Productivity and International Trade: Firm Level Evidence from a Small Open Economy," *Review of World Economics (Weltwirtschaftliches Archiv)*, December 2008, *144* (4), 774–801.

Behrens, Kristian, Gregory Corcos, and Giordano Mion, "Trade Crisis? What Trade Crisis?," August 2010. CEPR Discussion Paper no. 7956. London, Centre for Economic Policy Research.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum, "Plants and Productivity in International Trade," *American Economic Review*, September 2003, *93* (4), 1268–1290.

Beveren, Ilke Van, Andrew B. Bernard, Emily J. Blanchard, and Hylke Vandenbussche, "Carry-Along Trade," 2011. Katholieke Universiteit Leuven publication.

Bloom, Nicholas, Mirko Draca, and John Van Reenen, "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," January 2011. NBER Working Paper No. 16717. Cambridge, MA: National Bureau of Economic Research.

Bøler, Esther Ann, Andreas Moxnes, and Karen-Helene Ulltveit-Moe, "Technological Change, Trade in Intermediates and the Joint Impact on Productivity," March 2012. CEPR Discussion Paper no. 8884. London, Centre for Economic Policy Research.

Brunnermeier, Smita B. and Mark A. Cohen, "Determinants of environmental innovation in US manufacturing industries," *Journal of Environmental Economics and Management*, March 2003, *45* (2), 278–293.

Castellani, Davide, Francesco Serti, and Chiara Tomasi, "Firms in International Trade: Importers' and Exporters' Heterogeneity in Italian Manufacturing Industry," *The World Economy*, 03 2010, *33* (3), 424–457.

Eaton, Jonathan and Samuel Kortum, "Technology, Geography, and Trade," *Econometrica*, September 2002, *70* (5), 1741–1779.

Frondel, Manuel, Jens Horbach, and Klaus Rennings, "What triggers environmental management and innovation? Empirical evidence for Germany," *Ecological Economics*, May 2008, *66* (1), 153–160.

Glass, Amy Jocelyn and Kamal Saggi, "Innovation and wage effects of international outsourcing," *European Economic Review*, January 2001, *45* (1), 67–86.

Grossman, Gene M and Elhanan Helpman, "Quality Ladders and Product Cycles," *The Quarterly Journal of Economics*, May 1991, *106* (2), 557–86.

Horbach, Jens, "Determinants of environmental innovation–New evidence from German panel data sources," *Research Policy*, February 2008, *37* (1), 163–173.

Johnstone, Nick, Ivan Hai, and David Popp, "Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts," *Environmental & Resource Economics*, January 2010, *45* (1), 133–155.

Kasahara, Hiroyuki and Beverly Lapham, "Productivity and the Decision to Import and Export: Theory and Evidence," March 2008. CESifo Working Paper No. 2240.

Levinson, Arik and M. Scott Taylor, "Unmasking the Pollution Haven Effect," *International Economic Review*, 2008, *49* (1), 223–254.

Newell, Richard G., Adam B. Jaffe, and Robert N. Stavins, "The Induced Innovation Hypothesis And Energy-Saving Technological Change," *The Quarterly Journal of Economics*, August 1999, *114* (3), 941–975.

Pierce, Justin R. and Peter K. Schott, "Concording U.S. Harmonized System Categories Over Time," *Journal of Official Statistics*, forthcoming.

Popp, David, "Induced Innovation and Energy Prices," *American Economic Review*, March 2002, *92* (1), 160–180.

Vogel, Alexander and Joachim Wagner, "Higher productivity in importing German manufacturing firms: self-selection, learning from importing, or both?," *Review of World Economics (Weltwirtschaftliches Archiv)*, January 2010, *145* (4), 641–665.

Wooldridge, Jeffrey M., *Econometric Analysis of Cross Section and Panel Data*, Cambridge, MA: MIT Press. Washington, DC., 2002.