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Sourafel Girma, and Aoife Hanley

Abstract

There is a well-established theoretical and empirical literature that shows that exporters are more innovative than otherwise equivalent non-exporters. In this paper we ask whether this is also true when it comes to the effects of adopting greener production techniques. Using an instrumental variables strategy based on UK firm level data, we find robust evidence that exporters are more likely to report their innovation as having a 'high/very high' environmental effect.

Keywords: Environment and Trade, Technological Innovation

JEL: Q56, Q55

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1. Introduction

Economists largely disagree on the overall effects of trade on the environment. They generally agree, however, that newer technologies are better for environmental quality and that these newer technologies are enabled by trade (e.g. Levinson, 2007).[1] Early studies investigated the impact of trade on the environment using industry data. These early studies, however, have the drawback of masking substantial heterogeneity within industries, as pointed out by Cui et al. (2012). In fact there is now remarkably robust evidence that firms are heterogeneous even within narrowly defined industries (Bartelsman and Doms, 2000), that more efficient firms become exporters (Grossman and Helpman, 1995; Girma et al., 2008a) and that exporters are more likely to undertake technology upgrading (Bustos, 2011; Davies and Batrakova, 2012; Cui et al., 2012; Hanley and Monreal-Pérez, 2012).

Recent work has therefore shifted attention to firm level analysis. For example, Davies and Batrakova (2012) use firm-level data to examine the environmental premium from exporting. They find that technology upgrading has a positive effect on environmental quality. In this paper we ask whether exporters apply greener production techniques than non-exporters, and whether these techniques have more beneficial effects for the environment. The novelty of our paper lies in our identification of exporting on environmental outcomes. Specifically, we endogenize the exporting decision.[2] In addition, we use an alternative measure of environmental quality, namely the effect of a firm's technology on the efficiency of energy and materials usage. Energy and materials efficiency is important for firms. This is because energy and materials are becoming increasingly expensive and firms which manage to economize on energy use can improve their profits and simultaneously reduce the amount of emissions for each unit of product produced.

[1] However, as Davies and Batrakova (2012) have pointed out, if trade (exporting) is endogenized, the positive effects for trade on environmental quality are less clearcut. They refer a study by Copeland and Taylor (1994) which shows ambiguous effects for trade.

[2] Davies and Batrakova (2012), in their excellent study, investigate increases in energy efficiencies as a function of the firm's exporting status in a framework that accounts for selection effects (propensity score matching (PSM) with difference-in-differences). PSM imposes tight restrictions on the data, i.e. that there are no omitted variables which correlate with the firm's decision to export which could co-determine the firm's subsequent energy usage patterns, hence 2SLS is the preferred specification if appropriate instruments are available. Frankel and Rose (2005) and more recently Managi et al. (2009), use aggregate data (country) level to examine emissions. Similar to us, these studies use 2SLS to endogenise trade. However, the level of aggregation does not allow these studies to also consider possible heterogeneity at the level of the firm which would impact on the decision to export.

To preview our results, our econometric estimates based on UK firm level data from 1998 to 2004, show that exporters are up to 16 percent more likely than non-exporters to report that their green technology adoption has a 'high-very high' impact on energy/ materials cost reductions. Exporters are found to be substantially more likely to state that their technology is instrumental in reducing negative environmental impacts.

Our paper is structured as follows. Section 2 summarises the relevant background literature, Section 3 presents our empiric al model and Section 4 discusses the key features of the data used. Section 5 presents the empirical findings and Section 6 concludes.

2. Related literature

At the aggregate level, trade theory describes three mechanisms by which the internationalization of firms can impact on overall emissions levels. The technique effect relies on a dynamic where trade gives rise to higher profits. These higher profits, in turn, can be invested in better quality production processes which are emissions-saving. The other two effects, the scale and composition effect are predicted to have an ambiguous effect on the environment.[3] Specifically, the scale effect means that trade allows a firm to expand its production. An expansion of production has implications for higher emissions in the producing country. The composition effect describes the reallocation of certain industries (typically high in emissions) to countries with a comparative advantage in these activities. This effect is a consequence of specialization. Copeland and Taylor (1994) predict ambiguous effects of trade on the environment. In their model, the industrialized countries (North) will specialize in clean production while the developing countries (South) will specialize in emissions heavy production. The overall effect of trade is ambiguous in the Copeland and Taylor model. This is because environmental policy (a choice variable), causes the technique effect to grow in importance as trade increases the prosperity of the South. Transfers then take place between the North and the South. By contrast, Kreickemeier and Richter (2012) predict an overall

[3] Kreickemeier and Richter (2012) suggest the existence of a 'reallocation' effect. This effect, describes the higher competitiveness (efficiency) of firms which are environmentally efficient as well. The 'reallocation' effect picks up on the observations made by environmental economists that firms which reduce waste / are more energy efficient enjoy a double-dividend of lower average emissions and higher overall efficiency (Cole et al., 2005; Cole et al., 2008a; Mazzanti and Zoboli, 2009)

negative effect of trade on emissions, if the emissions intensity of firms falls as firms become more productive.

Using Melitz's (2003) model of trade with heterogeneous firms as a framework and drawing on Bustos (2011), Cui et al. (2012) demonstrate that only the most productive firms can afford to upgrade their technology to an emission-reducing technology. Productive firms pay for technology upgrades out of higher cumulative profits. Accordingly, Cui et al. predict that exporters have reduced emissions intensities. Davies and Batrakova (2012) analyse the impact of exporting on a firm's energy consumption. Overall, their model predicts that the increase in energy use for exporting firms is negatively correlated with the energy intensity of exporters. Although energy use rises with exporting due to increased production and transportation costs, this can be more than offset by the adoption of a more energy-efficient technology.

We now turn to existing empirical evidence. Assessing the concentration of the pollutant sulphur dioxide in over 40 countries over a timeframe of 25 years, Antweiler et al. (2001) find that the strongest positive effect for environmental quality is due to the technique effect. Cole and Elliott (2003) confirm this finding by investigating two other emissions, carbon dioxide and nitrogen dioxide.[4] Frankel and Rose (2005) conclude that trade does not have a detrimental effect on emissions, and argue that higher income generally implies higher environmental quality. This is because firms can upgrade production and more discerning customers can afford to pay a premium for green products.

Cole et al (2005) report that even when they have controlled for energy usage, that UK industries with higher physical capital intensity face the highest clean-up costs. Cole et al. (2008b), using Chinese industry data, find that if industry sectors become more productive, that environmental quality improves as well. Managi et al (2009) uncover evidence of a positive effect of trade on environmental quality for OECD countries. However, their results are mixed for the generally poorer, non-OECD countries. McAusland (2010) also find a positive effect from trade, but only locally.

Davies and Batrakova (2012) consider firm selection into exporting using Propensity Score matching combined with difference-in-differences. Interestingly, when the authors split their sample

[4] The positive effect for environmental quality is noted for sulphur dioxide emissions but not for the other emissions examined in the study

by median energy use, their estimations reveal that high energy intensive firms experience a dip in energy intensity in the two years following the decision to export. This may suggest the adoption of a cleaner technology.

What can we conclude from our reading of the literature? From Cui et al. (2012) we can infer a positive effect of exporting on emissions intensity. From Davies and Batrakova (2012) we have a prediction that exporting is accompanied by improvements in the energy efficiency of firms. From Girma et al. (2008b) we have the prediction that a firm's move to exporting permits it to invest in cleaner, upgraded technology. Finally, several studies have outlined how at least locally, trade induces a technique effect which improves environmental quality (Antweiler et al., 2001; Cole et al., 2003; McAusland, 2010). Additionally, there are indirect effects from trade. Rising incomes, which are a consequence of increased trade, change the composition and levels of consumer demand. This in turn, has an effect on the environment (Frankel and Rose, 2005; Managi et al., 2009). Overall we can derive the following testable hypotheses from the existing studies:

Hypothesis 1: Firms which begin exporting should show increased post-exporting energy efficiency (from Davies and Batrakova, 2012)

Hypothesis 2: Firms which begin exporting should report improved environmental impacts from their technology (from Girma et al, 2008b; Cui et al., 2012; Bustos, 2011).

3. Empirical Methodology

Our aim is investigate whether exporters use technologies that 1) lead to energy/ inputs cost cuts and 2) are associated with higher environmental impacts. To this end, we estimate the environmental innovativeness of exporters vs. non-exporters, having controlled for productivity differences and additional covariates as has been proposed in similar analyses (Dean and Lovely, 2008; Eskeland and Harrison, 2003; Dasgupta et al., 1998; Cole et al, 2005; Hanley and Monreal-Pérez, 2013).

Our measure of how green is a firm is important (See Appendix 1 for full list of variables). It is a 4-point ordinal response where firms are asked to report the 'Degree of impact' of their innovation with answers ranging from *'none'* to '*high'*. The questions elicit from respondents whether their technology led to 1) 'Reduced materials and/or energy per produced unit' and 2) 'Improved environmental impact or health and safety aspects'. Although, these measures are self-reported, a point in their favour is that they are direct and firm-specific. Moreover, similar firm-specific, self-reported measures have been successfully used by others who have used micro data in different contexts.[5] Our first measure of the extent to which a firm's technology is green, TECH_COSTS, has high internal validity. TECH_COSTS measures higher energy and resource efficiency resulting from innovation used in the firm. Our second measure of environmentally friendly innovation, TECH_ENVIRON is a composite measure. The responses given by firms to the questions on environmental innovativeness are measured on a 4-point scale. We therefore use an ordered Probit model with clustered standard errors (at the firm-level) that are robust to arbitrary heteroskedasticity and within-establishment serial correlation. Our baseline ordered probit model is specified as:

$$Pr(y_{it}) = Pr\left(\mu_{j-1} < \beta_1 EXP_{it} + \beta_2 PROD_{it} + \beta_3 EXP_{it} * PROD_{it} + X_{it}\gamma + \varepsilon_{it} < \mu_j\right)$$

In the above model *y* is our measure of environmental efficiency/environmental quality which takes the values of j = 0, 1, 2 and 3 as discussed earlier, *i* and *t* represent indices for the firm and year respectively, the μs are latent utility threshold parameters and ε is the error term. On the other hand, *X* is a vector of control variables which we include in line with previous work. Thus we follow Dean and Lovely (2008) and include *SKILL* (percentage of university educated employees in industry)[6] as a covariate. We also use firm size, measured by the number of employees, as an additional covariate. The inclusion of size is in line with existing studies (Dasgupta et al., 1998; Cole et al, 2005). The variable *FDI* describes the presence of foreign owned firms in the 4-digit sector. We calculate foreign presence from the FAME database of UK registered firms[7]. We include *FDI* on the basis that foreign firms are significantly more energy efficient and use cleaner types of energy (Eskeland and Harrison, 2003; Dean and Lovely, 2008). Indeed, Cassidy et al. (2005) found that it was the domestic firms who

[5] e.g. Criscuolo and Haskel (2003) who look at the self-reported introduction of new or advanced products/ processes and Belderbos et al., (2004) who examine inter-firm cooperation

[6] Dean and Lovely (2008) alternatively formulate skills as the ratio of skilled to unskilled workers in an industry.

[7] The standard UK Office for National Statistics criteria for foreign ownership is used: a majority shareholding or foreign registration.

most benefitted from export induced productivity because foreign-owned firms had less to learn.[8] Our specification also includes a CIS (Community Innovation Survey) survey wave indicator and sectoral dummies.

Two key covariates in our model are *EXP* which is a dummy variable denoting whether a firm exports and *PROD* i.e. firm level labour productivity. [9] *PROD* is measured alternatively as 1) productivity relative to the industry average and as 2) a series of dummy variables corresponding to productivity quintiles. We expect that more productive firms are more likely to say that their technology is environmentally friendly on the basis that more productive firms can afford to upgrade their technology to a state-of-the-art technology. Finally, we include an exports-productivity interaction term. We include this final variable to analyse exporting firms' input and energy efficiency with rising productivity.

4. Database construction and sample characteristics

We use data from several sources. Our main firm-level information on the extent to which a firm uses inputs and energy saving production techniques, is drawn from the UK Community Innovation Survey. We also collate data at the 2-digit industry level from the Bureau Van Dijk database of UK firms.

The CIS survey is administered every alternate year to a representative sample of UK businesses drawn from the registrations database. A major advance of the survey which we exploit for our work is that for the first time, firms in the third survey (CIS3) and fourth survey respectively (CIS4) could be merged into a workable panel.[10] Table 1 shows the breakdown of our panel when matching the two consecutive cross-sections.

(Table 1 here)

[8] Unfortunately, we do not have a dummy denoting whether a firm is foreign or domestic owned in our data. Applying the Cassidy et al (2005) intuition that it is domestic owned firms that benefit most from exporting, our data which averages results over all firms must be considered a lower bound. Any real effects should be higher for averages taken over domestic owned firms on their own

[9] Labour productivity was used in lieu of total factor productivity due to the omission of information on capital stocks in the CIS

[10] Other researchers who have constructed panels from these survey cross-sections are Criscuolo and Haskel (2003) and Belderbos et al. (2004) for the UK and Netherlands respectively.

The first cross-section comprises the period 1998 to 2000 and the second cross-section represents the period 2002 to 2004. Altogether we created a panel of around 950 firms for the period 1998 to 2004. Several things are clear from the matching process. First, there was a relatively high attrition in the sample between the two survey waves. Just over 13 percent of the firms could be matched from the original survey. We do not know to what extent firms were lost to the panel due to non-response or the possibility that some of the firms sampled in CIS3 had ceased to trade/ trade under their former name by the time they were sampled in CIS4. Roughly similar firms were sampled in both waves of the CIS. The statistics for the two survey waves indicate that firm size in the latter wave is slightly lower (lower median turnover and slightly higher variance for turnover).

Overall, CIS firms were larger than firms in the more well known FAME database of UK firms taken from the population (Table 2) where the median CIS firm had circa 280 employees in any survey year and the corresponding number for the FAME data stood at around 60 employees. We now need to consider, at this point, how we can generalize from findings which will be based on the merged CIS panel to firms in the general population.

We know from comparisons with the FAME database, that the firms in our sample are larger and healthier, on average, than firms in the general UK population. Any technology induced effects from exporting are likely to be more pronounced for smaller firms because smaller firms are not as embedded as larger firms in global production networks. They rely more heavily on exporting to sell additional output. If we find in our analysis (estimated for larger firms) that exporting causes firms to report higher energy cost savings from the technology that they use, then our result must be considered a lower-bound because it underestimates the true effect for firms in the population.

(Table 2 here)

Mercer (2004) in her description of the CIS, reports how the VAT registrations database is used to identify the sample frame for the CIS. The VAT registrations database for the UK, referred to as the Interdepartmental Business Register (IDBR) and administered by the Office for National Statistics provides the most exhaustive listing of UK firms of all sizes, sector and establishment type. Firms in 12 broad industrial sectors with at least 10 employees were identified for the sample frame. The survey was administered to firms in such a way that they were statistically representative of firms in the population. The response rate was approximately 43 and 58 percent for the CIS3 and CIS4 surveys respectively. Given that exporting status represents a key variable in our analysis, we counted the share of exporters in any sector for the final year of the survey (2004). From the latter, we calculated the percent of exporters active in each 3-digit sector for firms in our data for which we had clear sectoral descriptions. In general, many sectors have a large share of exporters. Of the 3,076 firms in our dataset, 62 percent are exporters.

This value of 62 percent is on the high side compared to a study like Bernard et al. (2007). Bernard et al, using data from the US Census of Manufactures, cite an exporting share of 18 percent.[11] From Table 3, we can see that some of the traditional domestic industries such as Shipbuilding (Boat Repair) and Publishing have a low share of exporters.

(Table 3 here)

Light, specialized industries (Lighting, Electronic Components, Recording Instruments), have higher shares of exporting firms. We repeated this exercise for the number of firms in each sector in 2004 who stated that new technologies introduced by their firm had a 'high-very high' impact on environmental quality (Table 4). Here industries which are geared around industrial processes (manufacture of paper, soaps and detergents) show very prominently in the rankings. These industrial activities have the potential to cause severe environmental degradation.

(Table 4 here)

The limitation of these tables is that they summarise the information in a uni-dimensional way and are not that revealing except to confirm that our measures of exporting and energy/materials-saving production techniques are behaving as expected. Much more interesting would be the question of how the technologies of individual firms impact on the environment. It is important, however, to view these impacts having controlled for important inter-firm differences such as size and productivity. Indeed, firms in the traditional 'dirty' industries may pay comparably more attention to environmental impacts, especially if they are large industries and therefore highly visible to consumers. This makes

[11] However, our firms are UK firms from a comparatively open economy with many exporting firms. Also having matched two waves of the Community Innovation Survey introduces a 'survival bias' i.e. larger firms which can afford sunk exporting costs and similarly more likely to survive to the second survey period are better represented in our data.

it more imperative to control for inter-firm differences such as size and sector.[12] Table 5 provides some summary statistics for the key variables used.

(Table 5 here)

Exporters, in line with stylized facts, are larger (higher number of employees and sales) and more productive than non-exporters. Exporters are also are more skill intensive (median firm belongs to 4-digit industry where 7 percent of payroll staff are university educated vis-à-vis. 2 percent for non-exporters). Table 6 reports the composition of the two response variables, 'TECH_COSTS' and 'TECH_ENVIRON' over the 2 survey waves.[13]

(Table 6 here)

Interestingly, although about 60 percent of the firms in the sample report no innovation impacts for either environment measure for the first survey wave, proportionately few respondents (circa 30 percent) report no environmental impacts in the second wave.[14] Our estimates reveal that 18 percent of firms classify their innovation as having a 'high' effect in bringing about environmental improvements/safety.[15]

5. Empirical Findings

Let us begin by recalling our initial hypotheses. From Davies and Batrakova (2012), we hypothesize (Hypothesis 1) that firms which begin to export should show increased energy efficiency. We also expect in line with other studies (Girma et al, 2008b; Cui et al., 2012; Bustos, 2011) that firms which begin exporting should be able to show improved environmental impacts from their technology (Hypothesis 2). We these starting hypotheses in mind, we first estimate a simple ordered Probit in Table 7 where our response variable 'Effect of innovation on Energy & Materials costs' is regressed on the exporting dummy 'EXP'. The coefficient for the latter is positive and significant. More

[12] What is less easy to eliminate in regressions is the practice of `greenwashing` where firms make cosmetic changes in order to improve their public image.
[13] For non-missing firms
[14] These intertemporal differences could be systematic due to changes in the question phrasing or they could be a consequence of greater environmental awareness over the intervening years. This is why we run the subsequent ordered Probits as individually as cross-sections before estimating as pooled panels. The estimations, available on request, do not change the positive association between exporting and environmental innovation.
[15] This breakdown is roughly in line with a similar figure of 15 percent reported in the Technopolis Report (2008) using similar data for respondents from various EU member states. Therefore, we are reassured that the breakdowns have not suffered through the matching and data cleaning process.

interestingly, when we examine the marginal effects for the 4 categories of the response variable, we see that exporters are 9.6 and 6 percent more likely to report a ‘very high effect’ or ‘high effect’ respectively of their improved technology (innovation) on the environment. Taken together, we can see that exporters are 16 percent more likely to report that their innovation exercises a ‘high/very-high’ effect on their energy/materials costs. Exporters are also nearly 14 percent less likely to report that innovation has no effect, compared to non-exporters.

Surprisingly, firms which have higher productivity are not significantly more likely to report high effects for their improved technology (innovation) on the cost of inputs. However, the effect although insignificant has the expected positive sign. Moreover, increases in exporter productivity (PROD* EXPORTER) do not result in higher impacts of innovation on input efficiency. However, adding together the effects for the productivity and exporter interactions still gives an overall positive effect for exporters. Table 7 therefore gives us results which are consistent with Hypothesis 1, that exporting firms should show increased energy efficiency.

(Table 7 here)

To examine whether Hypothesis 2 is true, we also estimate the ordered Probit for the ‘Improved Environmental Impact’ measure and similarly find a significantly positive relationship for the exporting dummy. Specifically, we find a ‘high-very high’ effect of a firm’s innovation in reducing material/ energy costs. Exporters are 8 percent more likely to report that their innovation has a ‘high-very high’ effect in reducing environmental impacts.

(Table 8 here)

Analogous, with our earlier findings in Table 7 for energy efficiency, there is no positive effect from higher exporter productivity. This brings us to ask whether our findings for the exporting dummy are driven by some unobserved influence which is correlated both with the response variable, our energy efficiency proxy, ‘Reduced materials and/or energy per produced unit’ and the exporting dummy. One way out of this impasse is to instrument the exporting variable. Fortunately, we have access to two suitable instruments that jointly offer a reasonable explanation for exporting behaviour in our data whilst being uncorrelated with energy efficiency.[16] These are the contemporary and lagged values of the outsourcing status of Irish firms to the UK (*RATIO_OUTS4).* These variables were obtained from a separate firm level data source.[17] Specifically, *RATIO_OUTS4* represents the ratio of internationally outsourced materials at the 4-digit industry level for each firm. We expect that firms in industries with extensive UK outsourcing are more likely to be integrated into foreign production networks. Such UK outsourcers are accordingly more likely to export part of their manufactured end-product. The use of these instruments, if appropriate, should help us to account for the endogeneity of exporting in relation to technology upgrading, and to identify the true effect of exporting on greener production.[18]

Indeed, we can see from the first-stage regression in Table 9, that both the actual and lagged values for our instrument are positively related to the firm's likelihood to export. The partial R-square value for the instruments is reassuringly significant as is the Anderson LR statistic for the relevance of the instruments. The Hansen test for overidentifying restrictions also confirms the exogeneity of the instruments.

(Table 9 here)

In Table 10 we report the results for energy and inputs efficiency. Exporting is positively and significantly associated with reduced environmental impacts and material and energy costs.

(Table 10 here)

6. Conclusion

The stylized fact that exporters are more productive than non-exporters and the theoretical prediction that exporters can more readily amortize the cost of energy/materials saving innovation makes for an interesting proposition: Are exporters greener than non-exporters? We tested this proposition using UK firm level data from 1998 to 2004. Our results lend empirical support to the

[16] We are grateful to Holger Görg for suggesting these instruments based on his knowledge of using the Irish Forfás data
[17] For a good overview of the Irish Forfás data, see "Exporting and the Environment: A New Look with Micro-Data", Kiel Working Paper Series, WP1423, June, 2008 by the same authors wp1423.pdf
[18]. See Abramovsky and Griffiths (2006) who similarly apply this technique.

hypothesis that exporters are more likely to denote their innovation as having a 'high/very high' environmental effect. All things equal, exporters are more likely to report that their firm's innovation cuts the cost of energy and materials (Hypothesis 1). Also exporters use innovations which have significantly higher environmental impacts (Hypothesis 2). In sum, our findings show that exporters are more likely to say that their technology impacts on the environment. Can we generalize from our findings to exporters from any country? And, what implications does the composition of exports (e.g. percentage of exports to OECD vs. non-OECD economies) have for the outcome of our analysis? We answer each of these questions in turn.

Firstly, we recall that our data is for the UK. The UK, similar to many rich developed countries, has a generally clean manufacturing base.[19] It should be further pointed out that UK firms exported the overwhelming share of exports, to rich, developed countries (86 percent in 2004 according to the World Development Indicators, 2012). Firms in these rich countries similarly manufacture to tight environmental standards. Jaffe et al. (1995) pointed out that differences in international environmental standards have little effect for firms in richer countries. This is because environmental compliance is not the most important factor which determines the extent to which a firm's technology is environmentally friendly. The important factor is for exporting firms to use modern technologies in order to stay internationally competitive. We can, by extension, say the same is true for firms within the United Kingdom. The main impact of an exporting firm's technology on the environment is unlikely to be a response to tighter international environmental standards since the UK, like other wealthy economies, already subjects its manufacturers to tight environmental standards. A more likely explanation is the competitive pressure on exporting firms to build modern, state-of-the-art facilities. If exporters have a higher ability to introduce such modern production facilities, then it is reasonable to argue that the technologies used by exporters have heightened effects on environmental quality.

Let us now interpret our findings in context with other studies and suggest promising areas for future work related to our findings. Our findings echo the positive effects from exporting seen in Cole

[19] The World Development Indicators for the period under our analysis 2003-2005, show that UK energy efficiency (2 kg of CO_2 per kg of oil used) is broadly comparable with Germany and Japan. In terms of water quality, the UK fares also quite well (comparable to Denmark) with an average value for organic water pollutant of 0.17.

and Elliott (2003). The latter used country-level data to investigate emissions and found evidence of positive effects (combined scale and technique effects) for some environmental indicators. Technique effects have been recorded in other studies which use aggregate data (McAusland, 2010; Antweiler et al, 2001). A further angle for future work would be to see whether similar effects hold for firms within a less developed economy. Do exporters in low- to middle-income economies similarly experience a heightened effect of their technology on the environment?

What implications do our findings have for current policy debates on trade and the environment? Exporting does not need to be damaging to the environment: quite the contrary. Even after instrumenting for exporting status of firms in our sample to reduce the bias caused when firms self-select into exporting, we find that exporting is associated with energy and materials saving innovation. We find robust evidence that exporters are more likely to report their innovation as having a 'high/very high' environmental effect.

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Table 1 Creating the Innovation Panel of UK firms

Unmatched firms from cleaned sample:				
CIS4: 2002-2004	15,486			
CIS3: 1998-2000	7,213			
Matched firms from both waves:				
Number of firms	959			
% of firms in CIS3 matched with CIS4	13.3			
Distribution of turnover:				
	N	mean	sd	median
1998 (from CIS3)	7,606	27,187	213,039	2,223
2000 (from CIS3)	7,931	35,211	389,883	2,597
2002 (from CIS4)	16,433	34,105	335,313	1,600
2004 (from CIS4)	16,437	39,816	439,953	2,000

Table 2 Comparison of Employment Size from FAME and CIS data

	FAME database				Community Innovation Database (CIS)				
year	mean	sd	p50	N		mean	sd	p50	N
1998	311	2,061	59	22,995	CIS3	488	893	276	760
2000	305	2,144	60	26,908					
2002	304	2,488	58	30,934	CIS4	504	1,111	284	769
2004	285	2,416	56	32,706					
						496	1008	282	1,529

Notes

FAME is a database of firms in the UK economy administered by Bureau van Dijk

Table 3 Sample of high/low exporting industries

	3-digit SIC	non-exporters	exporters	total	non-exporters (%)	exporters (%)	total (%)
Industries with low number of exporters							
Building & repairing of ships & boats	351	18	10	28	64	36	100
Publishing	221	24	20	44	55	45	100
Manufacture other foods	158	36	36	72	50	50	100
Manufacture Cars and Trailers	342	30	34	64	47	53	100
Industries with high number of exporters							
Manufacture of lighting equipment & electric lamps	315	0	12	12	0	100	100
Manufacture of electronic valves & components etc.	321	0	28	28	0	100	100
Manufacture of television, radio receivers etc.	323	0	48	48	0	100	100
Manufacture of optical instruments & photographic equipment	334	0	8	8	0	100	100

Table 4 Sample of Reported Impacts of Firm's Technology on Environment (*TECH_ENVIRON*)

		impacts				impacts (%)			
	SIC3-digit	none	some	high/very high	total	none (%)	some (%)	high/ very high	total (%)
Industries with high/very high reported impact									
Manufacture of pulp, paper etc.	211	6	2	16	24	25	8	67	100
Manufacture of builders' carpentry & joinery	203	2	2	8	12	17	17	67	100
Manufacture of soap & detergents etc.	245	0	10	10	20	0	50	50	100
Manufacture of basic precious & non-ferrous metals	274	0	8	8	16	0	50	50	100
Industries with lower reported impact									
Manufacture of electricity dist. equipment	312	6	4	6	16	38	25	38	100
Manufacture of lighting equipment & electric lamps	315	4	4	4	12	33	33	33	100
Manufacture of textiles	174	2	4	2	8	25	50	25	100
Publishing	221	20	14	10	44	45	32	23	

Notes: Descriptions come from 3-Digit UK Standard Industrial Classification Revision 2003. A full table for all industries is available from authors on request

Table 5 Summary Statistics

	Productivity (£,000)	Employees	SKILL (% university graduates in industry)	Sales (£,000)
Exporters				
Median	84	298	7	25,552
Mean	102	429	13	52,010
Standard deviation	58	614	17	105,443
Observations	1,004	1,004	926	1,004
Non-exporters				
Median	66	117	2	10,838
Mean	75	241	6	19,338
Standard deviation	39	301	14	29,678
Observations	228	228	222	228

Table 6 Breakdown of Environmental Measures: 2 CIS Survey Waves

	CIS3 (1998 - 2000)		**CIS4 (2000 - 2002)**	
Impact	**Energy/Materials Costs** (*TECH_COSTS*)			
	freq	**%**	**freq**	**%**
None	441	57	222	29
Low	171	22	101	13
Medium	125	16	217	28
High	32	4	229	30
Impact	**Innovation has improved environmental/ other impacts** (*TECH_ENVIRON*)			
	freq	**%**	**freq**	**%**
None	423	55	256	33
Low	166	22	156	20
Medium	129	17	219	28
High	51	7	138	18

Table 7 Exporting, Productivity and Energy/Materials Costs: with relative productivity

Ordered probit: 4 Categories ($y_1 – y_4$): Innovation has 'no-effect', 'some-effect', 'high-effect', 'very-high effect' on Energy/Materials Costs					
	Coeff. estimates	**Marginal effects**			
		$\frac{\partial P(y=1)}{\partial x}$	$\frac{\partial P(y=2)}{\partial x}$	$\frac{\partial P(y=3)}{\partial x}$	$\frac{\partial P(y=4)}{\partial x}$
EXP	0.394***	-0.139***	-0.017***	0.060***	0.096***
	(0.062)	(0.023)	(0.002)	(0.011)	(0.013)
PROD	0.050	-0.017	-0.003	0.007	0.013
	(0.036)	(0.012)	(0.002)	(0.005)	(0.010)
*EXPORTER*PROD*	-0.104***	0.035***	0.007***	-0.014***	-0.028***
	(0.039)	(0.013)	(0.003)	(0.005)	(0.010)
SIZE	0.187***	-0.063***	-0.012***	0.025***	0.050***
	(0.014)	(0.005)	(0.001)	(0.002)	(0.004)
SKILL	0.000	-0.000	-0.000	0.000	0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	0.201**	-0.067**	-0.013**	0.027**	0.054**
	(0.088)	(0.030)	(0.006)	(0.012)	(0.024)
Survey dummy	yes				
Sector dummy	yes				
Observations	1676				
Log Likelihood	-2100.44				
Pseudo R-squared	0.086				
Model chi-squared	765.93				

Notes:

(i) Standard errors robust to heteroskedasticity and within establishment serial correlation in parentheses.

(ii) Significant at 10%; ** significant at 5%; *** significant at 1%.

(iii) Survey wave and industry dummies are included in the model. Estimations for manufacturing only (Standard Industrial Classification (92) 1500 to 36640)

(iv) Marginal effects give the marginal effect of the relevant covariate on the probability of the establishment undertaking environmental innovation at the specified level. For example, $\frac{\partial P(y=4)}{\partial EXPORTER} = 0.096$ implies that the innovation undertaken by exporters is 9.6 percentage points more likely to have very important effects on economizing on Materials and Energy inputs

Table 8 Exporting, Productivity and 'Environmental Impact': with relative productivity

Ordered probit: 4 Categories ($y_1 - y_4$): Innovation has 'no-effect', 'some-effect', 'high-effect', 'very-high effect' on 'Environmental Quality'					
		Marginal effects			
	Coefficient estimates	$\frac{\partial P(y=1)}{\partial x}$	$\frac{\partial P(y=2)}{\partial x}$	$\frac{\partial P(y=3)}{\partial x}$	$\frac{\partial P(y=4)}{\partial x}$
EXP	0.205***	-0.076***	-0.002**	0.038***	0.040***
	(0.071)	(0.027)	(0.001)	(0.013)	(0.014)
PROD	0.137	-0.050	-0.003	0.025*	0.029
	(0.084)	(0.031)	(0.002)	(0.015)	(0.018)
*EXPORTER*PROD*	-0.143*	0.052*	0.004	-0.026*	-0.030*
	(0.084)	(0.030)	(0.002)	(0.015)	(0.018)
SIZE	0.159***	-0.058***	-0.004***	0.029***	0.033***
	(0.016)	(0.006)	(0.001)	(0.003)	(0.003)
SKILL	0.002*	-0.001*	-0.000*	0.000*	0.000*
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	0.443***	-0.161***	-0.011***	0.079***	0.093***
	(0.088)	(0.032)	(0.003)	(0.017)	(0.018)
Survey dummy	yes				
Sector dummy	yes				
Observations	1676				
Log Likelihood	-2159.33				
Pseudo R-squared	0.041				
Model chi-squared	483.22				

Notes:

(i) Standard errors robust to heteroskedasticity and within establishment serial correlation in parentheses.

(ii) Significant at 10%; ** significant at 5%; *** significant at 1%.

(iii) Survey wave and industry dummies are included in the model. Estimations for manufacturing only (Standard Industrial Classification (92) 1500 to 36640

Table 9 Exporting, Productivity and Energy/Materials Spend (1st stage: IVREG)

	Instrumental Variable Regression: 2-step	
	(1)	(2)
	Firm exports *(EXP: 1st stage OLS)*	Firm exports *(EXP: 1st stage OLS)*
SIZE		0.053***
		(2.75)
SKILL	0.010***	0.008*
	(2.70)	(1.92)
FDI	-0.101	-0.198
	(0.77)	(1.58)
PROD		0.044
		(0.85)
survey wave	yes	yes
sector	yes	yes
Instrument1: *RATIO_OUTS4*	0.237**	0.236**
	(2.46)	(2.54)
Instrument2: *L.RATIO_OUTS4*	0.087*	0.096*
	(1.93)	(1.83)
constant	0.661***	0.329
	(8.09)	(1.52)
Observations	669	599
R-squared	0.07	0.12
Partial r^2 of instruments	0.0195	0.0223
p-value for instruments	0.0012	0.0011

Table 10 Exporting, Productivity and Energy/Materials Spend (2nd stage: IVREG)

	(1) Environ. Impact *(TECH_COSTS)* *(2nd stage IV)*	(2) Environ. Impact *(TECH_COSTS)* *(2nd stage IV)*
EXP	1.884**	1.692*
	(1.97)	(1.80)
SIZE		0.070
		(0.98)
SKILL	-0.006	0.001
	(0.36)	(0.08)
FDI	yes	yes
PROD	no	yes
survey wave	yes	yes
sector	yes	yes
Constant	0.393	0.785
	(0.46)	(1.02)
Observations	669	599
Anderson LR statistic (IV relevance test)	2.77	2.50
χ^2	0.0643	0.0842
Hansen statistic (for overidentification)	1.376	1.593
χ^2	0.2408	0.2069

Notes:

(i) Instruments for exporting status are total ratio of internationally imported inputs for UK firms in Republic of Ireland (4-digit level) and the lag of this. We also used median rather than average amounts at 4-digit sectoral level in regressions not reported here

(ii) Standard errors robust to heteroskedasticity and within establishment serial correlation in parentheses.

(iii) Significant at 10%; ** significant at 5%; *** significant at 1%.

(iv) Time dummies are included in the model as is sectoral *FDI* and *SKILLS*

Appendix 1 List of Variables

EXP	Firm is an exporter (0/1)
PROD	Relative labour productivity
TECH_COSTS	Innovation reduced materials/ energy spend (0-3)
TECH_ENVIRON	Innovation improved environmental impact etc.(0-3)
SIZE	Logged employment
SKILL	Mean % university educated employees in the firm
FDI	FDI in 4-digit sector (sic92)
RATIO_OUTS4	Ratio of outsourced materials in 4-digit sector
L.RATIO_OUTS4	Lagged RATIO_OUTS4
SECTOR DUMMY	4-digit sector (sic92)
WAVE DUMMY	CIS wave indicator

Appendix 2 Environmental Questions from UK Innovation Survey

11. Effects of innovation

11.1 Please indicate the impact that your innovation activities have had on your enterprise in the period 1998-2000. *(please tick one box in each row)*

		Degree of impact			
		None	**Low**	**Medium**	**High**
	Reduced materials and/or energy per produced unit	☐	☐	☐	☐
Other effects	Improved environmental impact or health and safety aspects	☐	☐	☐	☐

Note:
Survey carried out every 3 years by the UK Office for National Statistics