

Semrau, Finn Ole; Hanley, Aoife

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Stepping up to the mark? Firms' export activity and environmental innovation in 14 European countries

Aoife Hanley^{a,b,c} and Finn Ole Semrau^{a,b} *

^a Kiel Institute for the World Economy

^b Kiel Centre for Globalization

^c University of Kiel

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Abstract

We investigate how a firm's export activity and country idiosyncrasies determine the firm's adoption of environmental innovation (EI) as well as the firm's decision to extend its number of EI typologies. To this end, we append two waves of the Community Innovation Survey, differentiate our sample of 14 European countries into advanced and less-advanced countries, merge the resulting data with export statistics from the World Input-Output Tables and apply a hurdle negative binomial model. In a finding new to the literature, we reveal heterogeneous effects in how the firm's export activity determines its EI adoption decision, depending on the country the firm is based and which foreign market the firm serves. We do not find any export destination independent environmental premium to export activity for firms based in an advanced country, which replicates prior studies mainly focusing on single countries. Conversely, for firms based in less-advanced countries, we observe that increased export activity boosts EI adoption and the number of EI typologies adopted. Moreover, our empirical analysis reveals for firms based in both country groups that exports towards environmentally demanding countries boost EI, while there is no environmental premium of exports towards emerging countries. The importance of the direction of trade provides a novel perspective on regulation-push and demand-pull mechanisms as determinants of EI adoption, normally investigated for domestic markets, and in our paper extended to foreign markets with a different set of stakeholders preferences.

- Investigate the effect of a firm's export activity on environmental innovation (EI).
- Effects differ with a firm's country of origin and export- market idiosyncrasies.

*Corresponding author: Finn Ole Semrau, Kiellinie 66, 24105 Kiel, Germany, e-mail: finn-ole.semrau@ifw-kiel.de, telephone: +49(431)8814-646

- Serving environmentally demanding markets boosts a firm's EI, for all exporters.
- A firm's exports only drive EI, for exporters from European less-advanced countries.
- The revealed environmental premium to exporters represents a hidden benefit of EU integration.

Keywords: Green/eco-/environmental innovation; Environment and trade; Export destination; Sustainable Development Goals 9 and 12

JEL Classification Numbers: F18, O31, Q52, Q56.

1 Introduction

The diffusion of environmental innovation (EI) is crucial for decoupling economic growth from environmental degradation and to pave the way towards a circular economy (Ana de Jesus, 2018). Accordingly, Sustainable Development Goals 9 and 12 cover EI in its many domains as a key driver for global sustainable development and an increasing number of studies investigate the determinants of EI adoption by firms (United Nations, 2017).¹ We take the spotlight on a firm’s export activity as a driver of the firm’s decision to adopt EI and the decision to extend the number of EI typologies adopted. New to the literature, we show that effects differ with firms’ home country and the level of environmental regulation in foreign markets.

In a single-country set-up, prior studies on the firm’s export activity as a modifier of the firm’s EI adoption decision do not find a positive relationship (Cainelli et al., 2012; De Marchi and Grandinetti, 2012; Chiarvesio et al., 2015), though Ghisetti et al. (2015) reveal, in a multi-country set-up, a positive impact of the firm’s export activity on the likelihood to adopt any EI. We follow the methodology of Ghisetti et al. (2015) and investigate the firm’s export activity as a modifier of the firm’s EI adoption in a multi-country set-up. The multi-country set-up enables us to reveal that exporters in relatively less-advanced countries step-up to foreign standards, while firms in advanced countries do not. Accordingly, we show that country idiosyncrasies of the firm’s home country explain different results of prior studies.

Moreover, we reveal a boost of firms’ EI adoption by exports towards countries with tight environmental policy stringency (EPS) in all countries, which provides a novel perspective on regulation-push and demand-pull mechanisms as determinants of EI adoption, normally investigated for domestic markets, and in our paper extended to foreign markets with a different set of stakeholders preferences.

Before going any further, we define what we mean by EI, in its conventional sense, EI is *“the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives”* (Kemp and Pearson, 2007, p.7).

The definition focuses on the innovation adoption phase and covers many EI typologies such as emissions abatement, reduction of water and soil pollution, increasing resource efficiency or crucial parts of a circular economy such as the introduction of re-

¹A consensus in the literature emerged on four clusters of determinants, namely: market-pull, technology-push, regulation-push and firm-specific factors (e.g.: Horbach (2008), Cainelli et al. (2012), De Marchi (2012), Horbach et al. (2012), Kesidou and Demirel (2012), Borghesi et al. (2015), Ghisetti and Pontoni (2015), Ghisetti et al. (2015), Barbieri et al. (2016) and Horbach (2016)).

cycling (Kirchherr et al., 2017, 2018).² Additionally, it includes EI with an unintended environmental beneficial effect.

In a seminal contribution Rennings (2000) highlights a double externality characteristic of EI and stresses the need for researchers to view the determinants of EI adoption through a modified lens. Firms cannot fully appropriate returns of EI, because it produces two socially desirable externalities, namely knowledge and environmental externalities. The latter is a special characteristic of EI and does not apply for other innovation. Accordingly, Rennings (2000) concludes that regulation is of a particular importance to push firms towards a cleaner production, a finding backed by several studies (Jaffe and Palmer, 1997; Brunnermeier and Cohen, 2003; Horbach, 2008; Borghesi et al., 2015).

We extend regulation-push in the firm's EI adoption decision to the foreign market. However, environmental regulation highly correlates with environmental awareness and hence with the general demand for environmental quality by foreign stakeholders (Antweiler et al., 2001). In an analysis of the firm's export activity and engagement in Corporate Social Responsibility (CSR), Newman et al. (2018) state that the set of stakeholders preferences, including governments, buyers of intermediates and consumers, changes with entry into foreign markets. Higher demand for CSR in foreign markets pushes firms to strengthen CSR engagement compared to firms serving only the domestic market. We expect a similar mechanism in the context of EI and hypothesise that exports to the world's most environmentally demanding countries require the firm to step-up their environmental performance to satisfy foreign stakeholders demand.

De Marchi (2012) and De Marchi and Grandinetti (2012) emphasise that EI adoption requires the firm to explore knowledge sources beyond the existing ones, which makes external knowledge sources relatively more important for EI adoption compared to other innovations. Ghisetti et al. (2015) support this view and reveal that external knowledge sourcing boosts the firm's EI adoption and the number of EI typologies adopted. In the context of the firm's export activity, Ghisetti and Pontoni (2015) state that exports affect EI adoption only indirectly by an increase of firms' R&D engagement, however, we argue that trade induced knowledge spillovers directly affect the firm's EI adoption decision. De Loecker (2007) finds that the firm's export activity links to learning-by-exporting benefits. In particular firms from less-advanced countries can benefit from learning-by-exporting, because they have less likely domestically access to crucial knowledge about EI adoption, state-of-the-art technology and a skilled-labour force. Accordingly, we hypothesise that firms from less-advanced countries are more dependent on external knowledge sources (Horbach, 2016) and exporters from the latter more likely to benefit from knowledge flows (De Loecker, 2007). A hypothesis which helps to explain the differences in the findings

²Some authors use the terms eco-innovation and environmental innovation synonymously. However, Ghisetti and Pontoni (2015) highlight that eco-innovation represents a category of EI. Eco-innovation is associated with improvements in economic and environmental performance, while EI generally restricts itself to environmental performance.

between Ghisetti et al. (2015) and Cainelli et al. (2012), De Marchi and Grandinetti (2012) and Chiarvesio et al. (2015).

In the spirit of some recent EI studies, we apply multi-country data (Triguero et al., 2013; Ghisetti et al., 2015; Horbach, 2016), however, we split the 14 European countries in our sample into advanced and less-advanced countries. We test our hypotheses by applying a hurdle negative binomial model based on two appended waves of the Community Innovation Survey (CIS), merged with the World Input-Output Tables to include information on export destination and intensity. Moreover, we use the EPS index provided by the OECD as a measure of export market's stakeholders demand for environmental quality (Botta and Koźluk, 2014).

Summarising our key findings: We confirm Horbach (2016) that the firm's EI determinants differ between heterogeneous European countries. New to the literature, we transfer this finding to the context of the firm's export activity and reveal a strongly positive significant relationship for exporters from less-advanced countries, but not for exporters from advanced countries. Up to now, studies on the role of exporting in the firm's EI adoption decision focus on exporters from advanced countries. Additionally, to the best of our knowledge, we are the first who empirically show that exports to environmentally more demanding countries boost EI adoption in all countries. In advanced countries, tighter EPS in export-markets increases the likelihood of EI adoption and the number EI typologies adopted. In less-advanced countries, tighter EPS in export-markets strongly affects the firm's decision to extend the number of different EI typologies adopted. The revealed effect of EPS in export-markets on the firm's EI adoption decision illustrates that firms incorporate foreign stakeholders preferences in their production decision.

The following part gives an overview on the relevant literature on trade and the environment. Based on the literature review, we derive hypotheses about the interface of the firm's export activity and EI, which regarding for home-country and export-market heterogeneity.

2 Trade and the environment

Numerous studies document the environmental effects of trade (Cherniwchan et al., 2017). Specifically, three main channels for how trade affects the environment are identified (Copeland and Taylor, 1994; Antweiler et al., 2001; Frankel and Rose, 2005). First, theory predicts a negative scale effect for trade on the environment. This arises, because increases in trade are accompanied by a general increase in economic activity which raises overall pollution levels. Second, theory postulates a composition effect - as a country moves from autarky towards increased trade openness, economic activity adjusts into line with the country's comparative advantage. The sectoral composition of the economy shifts to reflect these changes in economic activity. Specifically, relatively dirtier

production gets reallocated from highly regulated countries to less regulated countries in a process known as the pollution haven hypothesis. Lastly, environmental economic theorists describe a technique effect. This latter channel for trade to impact on the environment arises when trade increases a country's level of income and with it the demand for environmental quality. If the government responds to reflect the swing in consumer preferences, environmental policy becomes more stringent. Increases in the stringency of environmental regulation generally induce firms to adopt more environmental-friendly production technologies or produce greener products. Accordingly, the level of pollution is predicted to fall via a technique effect.

Firms are heterogeneous even in narrow defined sectors and we hence turn to firm-level analysis. The Melitz (2003) model predicts that productive firms self-select into exporting and Bustos (2011) finds that these firms are also more likely adopt new technology. More recent studies show that exporting firms also produce more environmentally efficient. Batrakova and Davies (2012) focus on the effect of firms' exports on the energy efficiency and find that especially high energy users significantly increase their energy efficiency after export entry. Richter and Schiersch (2017) evaluate the effect of firms' export on physical CO₂ emissions in production and find that exporters have a reduced CO₂ emission intensity compared to their non-exporting counterparts. In line to this, Forslid et al. (2018) theoretically and empirically show that firms' export activity increases production and spending on CO₂ emission abatement, since firms face costs of pollution and can split fixed costs of abatement across more units of output.

All in all, the trade literature strongly supports the claim that a firm's export activity improves the overall environmental performance. We now take the literature on the firm's environmental performance to the context of EI, with its different domains and specific set of determinants compared to other innovation (Rennings, 2000; Kemp and Pearson, 2007; Barbieri et al., 2016). Girma and Hanley (2015) analyse the effect of firms' export on the energy use, material use and the overall improvement of firms' environmental performance. They find exporters are more likely to state that their innovations induce more environmental efficient production. Unfortunately, the survey design introduces some noise into their definition of EI (Richter and Schiersch, 2017).³ Other single-country studies on the firm's export activity as a modifier of its EI adoption do not reveal a positive effect (Cainelli et al., 2012; De Marchi and Grandinetti, 2012; Chiarvesio et al., 2015). However, we argue that this is caused by the particularities of EI compared to other innovation and neglecting country heterogeneity of the firm's home country and its export market. To this end, we derive our first hypothesis on the firm's export activity and EI, while accounting for the firm's home country development. Moreover, we in a second hypothesis, we account for foreign market idiosyncrasies as a driver of the firm's

³In their employed CIS wave it is not possible to distinguish between improvements with a beneficial effect on health and on the environment.

EI decision.

2.1 Firms' export activity and EI adoption

De Marchi (2012) makes the point that most studies on EI exclude non-innovative firms without controlling for any potential selection bias arising from making this distinction. However, the focus on innovative firms and accordingly the analysis of drivers of EI adoption that go beyond the ones of other innovations is reasonable, because of the above described double externality characteristic of EI (Rennings, 2000; Horbach, 2008). Nonetheless, the restriction of a comparison between EI and other innovation, reduces the generalisability and makes also a comparison to the results of the trade literature not straightforward (Ghisetti et al., 2015). In the following part, we follow the research path on the determinants of EI and continue to focus on the particularities of EI compared to other innovation.

Cainelli et al. (2012) analyse several aspects of EI, namely energy and material reduction, CO₂ abatement as well as increased emissions reductions for soil, water and air. Their results suggest no effect of a firm's export activity that goes beyond the returns to innovation. De Marchi and Grandinetti (2012) also use information of Italian firms and do not find an environmental premium of exports for both, the adoption of any EI and the decision to extend the number of different EI typologies.

Ghisetti et al. (2015) highlight the narrow focus on advanced countries and extends the sample to less-advanced European countries. Interestingly, they report a positive correlation between the firm's export activity and the likelihood of adopting any EI. In combination with prior presented results, which do not reveal any effect, we suspect differences in the magnitude of the effect of firms' export activity among countries. An expectation in line with Horbach (2016), who allows for heterogenous determinants between Eastern and Western European countries.

We build on the finding of the importance of country heterogeneity and argue that export activity requires firms to step-up to standards firms face in foreign markets, including competition, regulation and stakeholders interests. Moreover, trade induced knowledge spillovers and learning-by-exporting effect provide a possible explanation for the missing correlation between firms' export activity and EI in the presented single-country studies (Coe and Helpman, 1995; De Loecker, 2007). Accordingly, the move to trade with foreign partners allows firms to appropriate knowledge spillovers, e.g. access energy-efficient and environmentally friendly technologies (Verdolini and Galeotti, 2011). Learning-by-exporting might be more important for EI compared to other innovations, since its adoption is a rather complex task, requiring the need to explore knowledge sources beyond the already existing repository of industrial knowledge (De Marchi, 2012; Horbach et al., 2013; Ghisetti et al., 2015). Firms based in advanced countries are already in a posi-

tion to gain access to many sources of local knowledge, state-of-the-art technology and a skilled-labour force. In contrast, firms from less-advanced countries can environmentally benefit from knowledge flows and learning-by-exporting. In line to this, Horbach (2016) finds indication for technology flows from Western towards Eastern Europe.

Summarising, our first hypothesis builds on the discovery of the role played by country heterogeneity, firms expected step-up to foreign market's standards, the rather high complexity of EI compared to other innovations and the evidence for trade induced knowledge flows:

H1: *Firms' export activity boost EI only in Europe's less-advanced countries*

2.2 Foreign market idiosyncrasies and firms' EI adoption

The technique effect describes that with a country's development, the demand for environmental quality increases and if governments are responsive to the demand, they will increase environmental policy stringency (EPS) (Antweiler et al., 2001). Tighter environmental regulation can stimulate a firm's efficiency by promoting technological change (Porter and van der Linde, 1995).⁴ Accordingly, domestic policy-push through tightened environmental regulation and demand-pull through demand for environmental quality, represent significant drivers of the firm's EI adoption (Rennings, 2000; Brunnermeier and Cohen, 2003; Popp, 2005; Horbach, 2008; Kesidou and Demirel, 2012; Triguero et al., 2013; Borghesi et al., 2015).

Trade connects countries with different demand for environmental quality (Dasgupta et al., 1999; Antweiler et al., 2001). Hence, exporting firms are confronted with a different set of stakeholders preferences to those prevailing on its domestic market. Stakeholders preferences include the demand for sustainable production imposed by foreign governments, buyer of intermediates and consumers (Newman et al., 2018). Savona and Ciarli (2019) argue that the firm's introduction of an EI largely largely relies on the incentives the firm faces, while Brunnermeier and Cohen (2003) highlight the incentive for firms to satisfy increased export demand for green products and impose a price premium on these exports.

Chiarvesio et al. (2015) distinguishes between the type of markets firms serve, however, they limit their analysis to Italian firms, a country they describe as having a high level of consumer awareness and EPS. In line to Italian's idiosyncrasies, they do not detect an additional effect of firms' export activity on EI adoption and claim for further research. We follow the path of Chiarvesio et al. (2015) and evaluate the effects of environmental demand by foreign stakeholders relatively to domestic stakeholders demand.

Based on the stakeholders demand for environmental quality in the firm's home and export markets, table 1 simplifies our prediction for the effect of export orientation on

⁴Ambec et al. (2013) for a detailed literature review on the Porter hypothesis.

the firm’s EI adoption decision.

Table 1: Conjectured stakeholders demand for environmental quality to EI adoption, by export destination.

| Origin/ Destination | Less-advanced economy | Advanced economy |
|-----------------------|---|--|
| Less-advanced economy | Similar level of demand for environmental quality: No effect | Higher level of demand for environmental quality: Positive effect |
| Advanced economy | Lower level of demand for environmental quality: Negative effect | Similar level of demand for environmental quality: No effect |

If the firm’s country of origin and its export country share similar levels of environmental demand, exporting introduces little change in terms of exposing the firm to new norms for EPS or buyers demand. Accordingly, we expect no additional environmental premium to exports, over and above the premia from other types of innovation. However, if the firm considers exporting to a country with a relatively higher level of environmental demand, there is an incentive for the firm to step-up its environmental performance to a level comparable with that of competitors in the export destination country. Moreover, If knowledge and technology flows determine EI (H1), we expect that particularly exports to environmental demanding countries drive the firm’s EI, because these countries are equipped with a high level of knowledge on environmental-efficient production. Lastly, exporting to countries with a lower level of environmental demand does decrease the incentive to invest in EI adoption. Apart from this simplification, many firms still have to serve the domestic market and/or export to multiple destinations. Accordingly, firm’s engagement in EI does not necessarily decrease, because other stakeholders remain to be satisfied. However, if the share of foreign sales in lax environmental demanding countries is significantly high, there might even be an incentive to reduce investments in environmental friendly production.

We summarise our second hypothesis on the foreign market’s idiosyncrasies as followed:

H2: *Exports to countries with a relatively tighter environmental policy stringency (EPS) boost firms’ EI*

3 Empirical application

We present our data applied in the following part, before we turn to the empirical setting to test our hypotheses.

3.1 The Community Innovation Survey (CIS)

We exploited the harmonized European Community Innovation Survey (CIS) waves of 2008 and 2014 provided by Eurostat to test our derived hypotheses.⁵ The CIS includes a detailed coverage of firm-level information on innovation inputs, outputs, sources, effects, obstacles and modalities (Mairesse and Mohnen, 2010). Unfortunately, it is not possible to construct a workable panel, the data is self-reported and hence information is not completely objective (Ghisetti et al., 2015; Mairesse and Mohnen, 2010). Nonetheless, the CIS enables outstanding possibilities for firm-level analysis and is unsurprisingly commonly used for investigating the determinants of a firm’s EI adoption.

The definition of an innovation is based on the Oslo Manual interpretation of innovation, focussing on the firm’s adoption phase rather than the novelty of an innovation (OECD and of the European Communities, 2005).⁶ The CIS is collected every two-years and the waves of 2008 and 2014 include an augmented list of EI, in its many forms. The CIS 2008 covers nine and the CIS 2014 ten different EI typologies, respectively. There are slight differences in the formulation of the questions. Our analysis focuses on typologies, which are similar over both waves or which can be adjusted to ensure comparability, these are: Reduced material or water use per unit of output; reduced energy use or CO₂ footprint (reduce total CO₂ production); reduced air, water, noise, or soil pollution; replaced a share of materials with less polluting or hazardous substitutes; recycled waste, water, or materials for own use or sale; and for the benefits obtained during the consumption or use of a good or service by the end user: Reduced energy use or CO₂ footprint; reduced air, water, noise or soil pollution; facilitated recycling of product after use.

In line to Ghisetti et al. (2015) and Mairesse and Mohnen (2010), we focus on firms with product or process innovations, or innovation activity during the two survey periods. In addition, we excluded firms with non-systematic missing values of our variables of interest. All in all, our workable data set includes 25,942 observations of seven manufacturing sectors based in 14 European countries, including Germany, Italy, Cyprus, Greece, Portugal, Czech Republic, Estonia, Slovak Republic, Croatia, Hungary, Latvia, Lithuania, Romania and Bulgaria.⁷

Exporters are, on average, more productive than non-exporters and exports pushes the firm’s innovation adoption (Melitz, 2003). Our preview of the descriptive statis-

⁵Details about the data access are part of the appendix and can also be accessed at <https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey>

⁶The applied definition differs from the Schumpeterian approach (Schumpeter, 1934), which typically defines an innovation as the initial introduction of a new product, process, service or organization into the market.

⁷The seven manufacturing sectors are, NACE Rev. 2: C10-C12; C13-C15; C16-C18; C19-C23; C24-C25; C26-C30 and C31-C33. The analysis is also transparently described in our Stata do-files (Version 15.1), available on request. Italian and Irish data is only available in 2008 and Cyprus, Hungarian and Greece data is only available in 2014 (see also Ghisetti et al. (2015)). Anonymised data of other countries is unfortunately not available.

tics confirms this pattern. The sub-sample of innovation active firms comprises 75.5% exporters compared to a corresponding proportion of 51.8% among non-innovators. Accordingly, we notify that our analysed sample excludes many non-exporting firms and see our results on the effect of the firm’s export activity on EI as a lower benchmark.

The next part describes our econometric strategy.

3.2 Econometric strategy

We applied a hierarchical econometric model, namely the hurdle negative binomial model.⁸ The hurdle negative binomial model distinguishes between two stages. In a EI entrance stage, our dependent variable, EI , is a dummy variable that reflects if a firm has adopted any EI and coefficients were estimated by using a logit estimator.

Accordingly, we specified our first equation for a firm i , producing in sector z , located in country j at time t as:

$$(1) \text{ Environmental innovation}_{it} = \alpha + \beta_1 \text{export}_{it} + \delta_n \text{sector characteristics}_{zjt} + \gamma_n x_{it} + \eta_{zj}$$

In the second stage, EI_num is the dependent variable, which counts the different EI typologies a firm employs and is strictly positive. For the estimation the zero-truncated negative binomial estimator was applied.

Accordingly, our second equation is:

$$(2) \text{ Number of environmental innovations}_{it} = \alpha + \beta_1 \text{export}_{it} + \delta_n \text{sector characteristics}_{zjt} + \gamma_n x_{it} + \eta_{zj}$$

, with $\text{Number of environmental innovations}_{it} > 0$ and n being the respective index of the coefficients of the covered covariates.

In both specifications η_{zj} determines the error term clustered at the sector and country level.

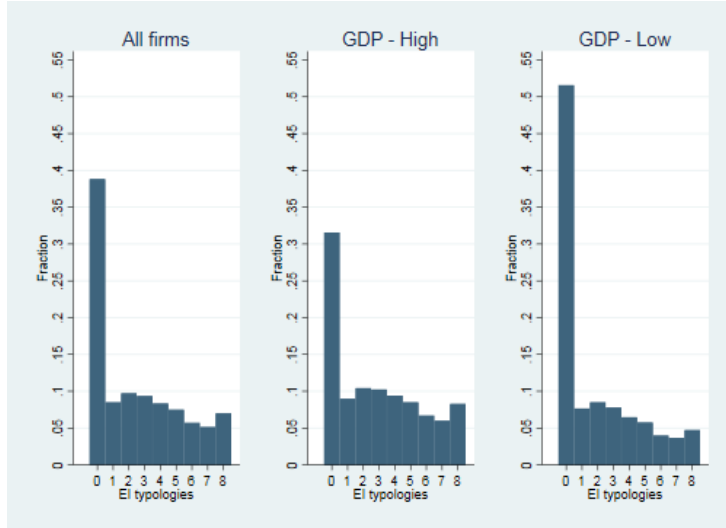
The choice of our empirical set-up fits the distribution of our outcome variable, because it allows for two different distribution generating processes for the adoption and diversification of EI, respectively (Cameron and Trivedi, 2013). Moreover, the zero-truncated negative binomial estimator outperform its alternatives in the presence of over-dispersion, which is the case in our sample.

To illustrate the properties of our outcome variable, it is useful to look directly at the breakdown of EI typologies adopted. Figure 1 depicts the distribution of the number of different EI typologies adopted. According to our hypotheses, we split the covered countries by the median of the GDP per capita in 2006 (The World Bank, 2018). This allows determinants to vary between groups of countries and is comparable to the separation in Eastern and Western European countries, as undertaken by Horbach (2016). However, we

⁸This is comparable to the empirical setting of Ghisetti et al. (2015).

expect that the relative development of individual countries dominates over geographic location in driving differences in EI outcomes.⁹ GDP-High countries are: Cyprus, Czech Republic, Germany, Estonia, Greece, Italy, and Portugal. GDP-Low countries are Bulgaria, Croatia, Hungary, Lithuania, Latvia, Romania, and Slovak Republic.

Figure 1: Number of EI typologies adopted split by country’s development (GDP per capita in 2006)



The graphs illustrate that zeros are overpresented in all specifications. A split by region reveals that especially in low-GDP countries, many firms do not adopt any EI. Truncating the sample to none-zero observations, does not lead to a Poisson distribution, because higher numbers of different EI typologies adopted, eight in particular, are overpresented. We now turn to our dependent variables, including our measures of firms’ export activity.

3.3 Dependent variables

Our first measure of a firm’s export activity, is a dummy for the firm’s export status. The *export* variable does not control for a continuous relationship with EI. To control if the level of trade integration affects the EI adoption rates, we merged data from the World Input-Output Tables (WIOT) (Dietzenbacher et al., 2013). The resulting data set enabled us to calculate lagged *export intensity* of each sector in each country at each time (2006 and 2012). On the one hand, Duchin et al. (1995) find that the firm’s adoption of improved production technologies, opens up new export possibilities, even before the firm takes the decision to export. On the other hand, the firm might enter a market and only subsequent to entry, begin to adopt greener technologies to satisfy increased foreign demand for greener production (De Marchi and Grandinetti, 2012). The lagged

⁹The results are widely robust against splitting the sample by geographic location (see robustness section).

export intensity reduces the causality concerns, even we acknowledge that the issue is not completely solved, because non-exporters, while remaining active in highly internationalised sectors, might decide to adopt EI prior to exporting in the future. However, in both cases - EI adoption before and after decision to export, respectively - we expect foreign idiosyncracies to co-determine EI adoption.

We distinguished between the level of stakeholders environmental demand in the export destination to test for the proposed mechanism via foreign demand. In our preferred specifications, we calculated the share country's sectors exported to the ten most environmental policy stringent (EPS) countries lagged in 2006 and 2012 (*export (EPS top 10)*). EPS is measured with an index provided by the OECD. The index ranges from zero (not stringent) to six (highest degree of stringency). The countries with the highest stringency score outperform other countries in the degree to which environmental policy imposes an explicit (or implicit price) on polluting or environmentally harmful behavior (Botta and Koźluk, 2014). In contrast to its common alternative, the pollution abatement cost and expenditure, the EPS index is comparable over time and across countries (Morales-Lage et al., 2016). Our proxy for foreign environmental demand (*export (EPS top 10)*), includes the exports towards France, Denmark, Finland, Sweden, Germany, Korea, Spain and Czech Republic, Austria and Netherland in 2006 and towards Denmark, Australia, Netherlands, France, Japan, Finland, Canada, Switzerland, United Kingdom and Norway in 2012.¹⁰ Lastly, we calculated the share exported to emerging countries such as BRICS members, for each country and sector at each time (*export (emerging)*).¹¹ In line to Antweiler et al. (2001), the EPS score clearly demonstrates that less-advanced countries have lower EPS scores, particularly observable by a significantly lower level of EPS in emerging countries. The role of *export (emerging)* in our analysis is two-fold. First, it controls if there is an incentive for firms to reduce EI adoption efforts, if there is a low environmental demand in the foreign market. Second, it serves as a control, since conversely to our exports to environmental demanding countries, we do not expect any positive environmental effect.

Our selection of our remaining control variables echoes a wide set of empirical studies on EI and refers to technology-push, regulation-push, market-pull as well as firm-specific factors (e.g.: Horbach (2008); De Marchi (2012); Ghisetti and Pontoni (2015); Ghisetti et al. (2015); Barbieri et al. (2016); Horbach (2016)). Since to the best of our knowledge, our study represents the first multi-country analysis on EI, applying data from the Com-

¹⁰Table 12 part of the appendix includes EPS scores ordered by the year 2006.

¹¹We applied the classification of the World Bank and define all countries as 'emerging' if their 'GNI per capita in US\$ (Atlas methodology)' is lower than 11,115 US\$ in 2006 and 12,615 US\$ in 2012 (The World Bank, 2018). Since the WIOT are not available for all countries, we decided against a further separation into lower middle income or low income countries. In 2006, emerging countries are: Bulgaria, Brazil, China (People's Republic of), Croatia, Indonesia, India, Lithuania, Latvia, Mexico, Poland, Romania, Russia and Turkey. In 2012, emerging countries are: Bulgaria, Brazil, China (People's Republic of), Indonesia, India, Mexico, Romania and Turkey.

munity Innovation Survey (CIS) for two points in time, the revealed coefficients can be viewed as a general robustness check of prior studies.

There is strong support for the view that foreign ownership promotes the firm’s environmental performance, hence we added the firm’s incorporation of the firm into an international group, *MNC* (De Marchi and Grandinetti, 2012; Chiarvesio et al., 2015; Brucal et al., 2017). Ghisetti et al. (2015) analyse the role of external knowledge sourcing by adding the breadth of knowledge sources in their analysis. Similarly, we captured the number of external cooperation partners involved in the innovation progress. Also similarly, we accounted for a non-linear relationship by adding the squared number of external cooperation numbers (*ext. coop. breadth*). A dummy for any internal *R&D* activity was included to proxy absorptive capacity (Horbach, 2008). Horbach (2008) shows that subsidies encourage the firm’s EI adoption, even if the subsidies are not targeted towards improving the environmental performance. Accordingly, we added a dummy if the firm has received any public support for its innovation the three years before the survey was conducted (*subsidies*).

Since the CIS does not directly allow us to control for impacts of environmental policy, we followed Ghisetti et al. (2015) and merged data on the sector/country/year combination provided by Eurostat. The EPS faced by an individual firm in each country/sector/year combination is proxied by the respective logarithm of carbon dioxide emissions relative to value added (*emission intensity*). A higher level of emissions to create one unit of output, is generally linked with a higher level of domestic regulation (Costantini and Crespi, 2008).¹² Lastly, we included firms turnover as proxy for size (*(ln) turnover*) as well as country, sector and year fixed effects.

In line with Horbach (2016), we expect the responsiveness of the firm’s EI adoption to specific determinants vary, depending on whether the firm’s home country is an advanced or less-advanced country. More precisely, we expect external knowledge sources (cooperation) and subsidies are especially important for firms located in less-advanced countries.

The highest correlation among independent variables is between *export intensity* and the two other measures of exports on the sector/country/year level (*export (emerging)* and *export (EPS top 10)*). To avoid multicollinearity, we did not include the three measures simultaneously in any individual specification. In terms of the bivariate relationship between these control variables, the highest correlations, 0.39 relates to *(ln) turnover* and the firm’s export activity. This mirrors Bustos (2011), who states that entry into foreign markets increases overall sales. Moreover, this illustrates that it is important to control for size to separate our effects of interest and scale effects. Since the level of correlation

¹²Data on ‘air emissions intensities by NACE Rev. 2 activity [env_ac_aeint_r2]’ is provided by Eurostat. Unfortunately, our variable of interest is only reported by all countries covered in our data set, from 2008. Hence, we have not introduced a lag. To improve consistency across both CIS waves (2008 and 2014), we have also used the data for 2014 rather than 2012.

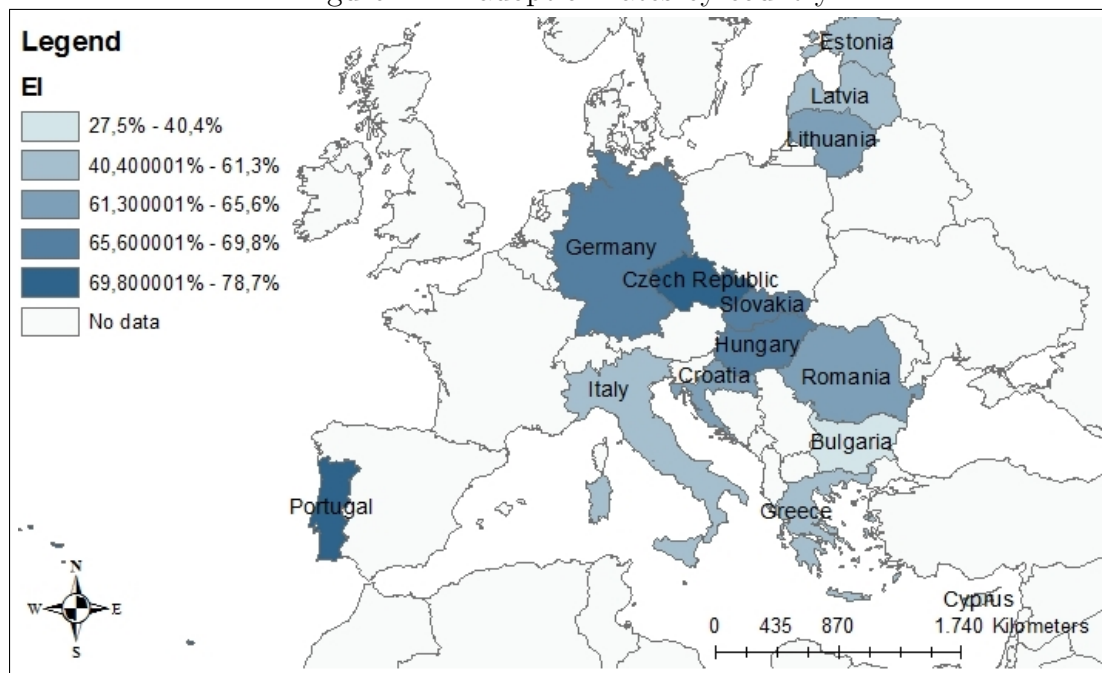
is still tolerable and we are satisfied that multicollinearity remains at reasonable levels.¹³

Before we employ our empirical investigation, we present descriptive statistics to provide insights on our variables of interest and the data in general.

3.4 Descriptive statistics

Figure 2 depicts the EI adoption rates in each country and table 2 additionally includes a split by export status.

Figure 2: EI adoption rates by country



61.2% of all covered firms have adopted at least one EI over the time period of three years before the survey. However, there is much heterogeneity between countries. At the upper end are Portuguese firms with a proportion of 78.7%. In terms of GDP, the per capita poorest country of our sample, Bulgaria, lies at the lower end of the distribution with 27.5%.

The remaining descriptives focus on the firm's decision to introduce any EI and its export status. Moreover, table 2 reports the results of a two-sample one-sided t-test to control if the differences between exporters and non-exporters are significant.

Interestingly, these descriptive statistics reveal that exporters (65.2%) are significantly more likely to implement any EI compared to non-exporters (49.0%). In Croatia, Germany, Greece, Lithuania and Romania exporters are not significantly more likely EI adopters. However, in Croatia, Greece and Lithuania the limited sample size of non-exporters makes it difficult to draw conclusions from the observed differences.

¹³The correlation table is part of the appendix

Table 2: Firms implemented any EI separated by geographic location and export status

| Country | All firms | | Exporters | | Non-exporters | | p-value |
|-----------------|-----------|--------|-----------|--------|---------------|-------|---------|
| | Yes | Total | Yes | Total | Yes | Total | |
| Bulgaria | 27.5% | 4,281 | 34.5% | 2,138 | 20.6% | 2,143 | 0.00*** |
| Croatia | 65.6% | 419 | 66.5% | 379 | 57.5% | 40 | 0.13 |
| Cyprus | 40.4% | 146 | 47.9% | 73 | 32.9% | 73 | 0.03** |
| Czech Republic | 73.4% | 3,032 | 74.8% | 2,587 | 64.7% | 445 | 0.00*** |
| Germany | 68.7% | 4,375 | 68.3% | 3,548 | 70.6% | 827 | 0.90 |
| Estonia | 58.9% | 873 | 59.7% | 808 | 49.2% | 65 | 0.05* |
| Greece | 61.3% | 654 | 61.9% | 528 | 58.7% | 126 | 0.25 |
| Hungary | 67.4% | 1,206 | 68.4% | 1,094 | 58.0% | 112 | 0.01** |
| Italy | 56.0% | 3,335 | 58.8% | 2,473 | 48.3% | 862 | 0.00*** |
| Lithuania | 63.9% | 743 | 63.6% | 670 | 67.1% | 73 | 0.72 |
| Latvia | 61.0% | 346 | 62.9% | 315 | 41.9% | 31 | 0.01** |
| Portugal | 78.7% | 4,120 | 79.2% | 3,287 | 76.8% | 833 | 0.07* |
| Romania | 65.3% | 1,815 | 66.3% | 1,117 | 63.8% | 698 | 0.13 |
| Slovak Republic | 69.8% | 597 | 71.3% | 533 | 57.8% | 64 | 0.01** |
| Total | 61.2% | 25,942 | 65.2% | 19,550 | 49.0% | 6,392 | 0.00*** |

Own calculations based CIS. Similar to the empirical analysis, the descriptive statistic focuses only on innovation active firms. P-values are depicted for a two-sample one-sided t-test. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

At the core of our H2 hypothesis, is the argument that regulation-push and demand-pull mechanisms by foreign stakeholders induce firms to adopt EI. Table 3 and 8 focus on firms' reported factors in decision to adopt an EI, accordingly the statistics focus on the subsample of EI adopters.

The descriptive results support our second hypothesis that environmental regulation and demand for environmental quality are driving factors for the firm's EI adoption decision. 58.7% of all environmental innovative firms state that environmental regulation, taxes, charges or fees have been a driving force in introducing an EI. Interestingly, the proportion is significantly higher among exporters than non-exporters, 60.6% vis 51.1%, respectively. A similar pattern is observable in the reported demand - current or expected - for EI adoptions, broken down by export status. 39.0% of the exporters and 28.0% of the non-exporters stated that demand for EI influenced their firm's behavior. Even the differences are not significant over all countries, they foster our claim that foreign stakeholders interests influence the EI adoption rate of firms.¹⁴

All descriptive statistics neither control for other factors driving the firm's decision nor account for the export intensity and destination. For this we turn to the econometric specifications.

¹⁴The according table is part of the appendix.

Table 3: Are environmental regulation, taxes, charges or fees driving factors in decision to introduce innovations with environmental benefits?

| Country | All firms | | Exporters | | Non-exporters | | p-value |
|-----------------|-----------|--------|-----------|--------|---------------|-------|---------|
| | Yes | Total | Yes | Total | Yes | Total | |
| Bulgaria | 49.4% | 1,179 | 56.4% | 738 | 37.9% | 441 | 0.00*** |
| Croatia | 83.3% | 275 | 82.9% | 252 | 87.0% | 23 | 0.69 |
| Cyprus | 78.0% | 59 | 74.3% | 35 | 83.3% | 24 | 0.79 |
| Czech Republic | 63.3% | 1,215 | 63.9% | 1,038 | 59.9% | 177 | 0.15 |
| Germany | 42.8% | 2,916 | 44.1% | 2,347 | 37.6% | 569 | 0.00*** |
| Estonia | 64.8% | 514 | 64.7% | 482 | 65.6% | 32 | 0.54 |
| Greece | 76.6% | 401 | 77.7% | 327 | 71.6% | 74 | 0.13 |
| Hungary | 68.1% | 813 | 67.1% | 748 | 80.0% | 65 | 0.98 |
| Italy | 45.6% | 1,717 | 47.7% | 1,343 | 38.2% | 374 | 0.00*** |
| Lithuania | 76.2% | 475 | 75.8% | 426 | 79.6% | 49 | 0.72 |
| Latvia | 64.5% | 211 | 63.6% | 198 | 76.9% | 13 | 0.83 |
| Portugal | 64.0% | 3,229 | 66.5% | 2,594 | 53.9% | 635 | 0.00*** |
| Romania | 71.5% | 1,186 | 74.0% | 741 | 67.4% | 445 | 0.00*** |
| Slovak Republic | 73.1% | 417 | 73.9% | 380 | 64.9% | 37 | 0.12 |
| Total | 58.7% | 14,607 | 60.6% | 11,649 | 51.1% | 2,958 | 0.00*** |

Own calculations based on the factors driving enterprise’s decision to introduce environmentally beneficial innovations. The CIS 2014 asks respondents to note the degree of importance, while CIS 2008 restricts responses to ‘yes’ and ‘no’. For the CIS 2014, we coded an answer as yes if the degree of importance is high or medium. Moreover, we merged the two options “existing environmental regulations” and “existing environmental taxes, charges or fees”. In Czech Republic only information for 2008 is available. P-values are depicted for a two-sample one-sided t-test. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4 Results and discussion

We start our discussion of the empirical results, with the first stage of the hurdle negative binomial model, before we estimate the effect of our covariates on the magnitude of EI typologies a firm adopt.

4.1 Firm’s export activity and EI adoption

Table 4 depicts the results of the logit regression. The first three columns include the full sample of firms from 14 European countries, while columns (4) to (6) focus on countries covered in the data set with a GDP per capita equal or in excess of the median value for the analysed countries in 2006. Columns (7) to (9) shed light on the determinants of EI for the less-advanced countries within the sample.

The first column links the analysis to the existing literature on the determinants of EI. As Ghisetti et al. (2015), *export* does significantly correlate with the likelihood of adopting any EI at the one-percent level of significance. However, we reveal country heterogeneity

Table 4: Hurdle negative binomial estimation results (logit part)

| VARIABLES | Dependent variable: Adoption of any EI | | | | | | | | |
|---------------------------------|--|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | (1) All | (2) All | (3) All | (4) GDP - High | (5) GDP - High | (6) GDP - High | (7) GDP - Low | (8) GDP - Low | (9) GDP - Low |
| Export | 0.187*** (0.058) | 0.186*** (0.058) | 0.185*** (0.058) | 0.077 (0.058) | 0.078 (0.058) | 0.077 (0.058) | 0.318*** (0.077) | 0.319*** (0.076) | 0.314*** (0.075) |
| Export intensity | | 0.165 (0.267) | | | -0.130 (0.226) | | | 0.927*** (0.327) | |
| Export (EPS top 10) | | | 0.884*** (0.328) | | | 0.840** (0.399) | | | 0.715 (0.455) |
| Export (emerging) | | | -0.430 (0.639) | | | -0.661 (0.712) | | | -0.125 (0.950) |
| MNC | 0.216*** (0.055) | 0.214*** (0.055) | 0.215*** (0.055) | 0.222*** (0.063) | 0.223*** (0.063) | 0.219*** (0.062) | 0.186* (0.096) | 0.181* (0.096) | 0.190** (0.095) |
| Ext. coop. breadth | 0.318*** (0.047) | 0.318*** (0.047) | 0.319*** (0.047) | 0.288*** (0.053) | 0.289*** (0.053) | 0.288*** (0.053) | 0.360*** (0.078) | 0.364*** (0.078) | 0.363*** (0.078) |
| Ext. coop. breadth ² | -0.012* (0.007) | -0.012* (0.007) | -0.013* (0.007) | -0.001 (0.007) | -0.001 (0.007) | -0.001 (0.007) | -0.026** (0.012) | -0.027** (0.012) | -0.026** (0.012) |
| R & D | 0.250*** (0.046) | 0.250*** (0.046) | 0.250*** (0.046) | 0.276*** (0.049) | 0.277*** (0.049) | 0.276*** (0.049) | 0.300*** (0.103) | 0.299*** (0.102) | 0.301*** (0.103) |
| Subsidies | 0.170*** (0.050) | 0.170*** (0.050) | 0.174*** (0.051) | 0.045 (0.050) | 0.045 (0.050) | 0.049 (0.050) | 0.487*** (0.070) | 0.481*** (0.071) | 0.487*** (0.071) |
| (ln) turnover | 0.026 (0.041) | 0.026 (0.041) | 0.026 (0.041) | -0.020 (0.050) | -0.021 (0.050) | -0.020 (0.050) | 0.131*** (0.017) | 0.130*** (0.016) | 0.131*** (0.017) |
| (ln) emission intensity | 0.054 (0.038) | 0.051 (0.039) | 0.062 (0.038) | 0.124*** (0.036) | 0.126*** (0.035) | 0.118*** (0.037) | -0.020 (0.071) | -0.028 (0.075) | -0.009 (0.068) |
| Observations | 25,942 | 25,942 | 25,942 | 16,535 | 16,535 | 16,535 | 9,407 | 9,407 | 9,407 |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Pseudo R ² | 0.132 | 0.132 | 0.133 | 0.0734 | 0.0734 | 0.0738 | 0.173 | 0.173 | 0.173 |
| Prob > Chi ² | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Log Pseudol. | -15,036 | -15,035 | -15,029 | -9,553 | -9,553 | -9,550 | -5,391 | -5,386 | -5,389 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

in the importance of firms' export activity in EI adoption. In our sample of advanced countries, we do not observe any environmental returns to exports (column (4)). This is in line to the single-country studies of De Marchi and Grandinetti (2012) and Chiarvesio et al. (2015). Conversely and new to the literature, firms from less-advanced countries stand to significantly benefit from export activity (column (7)). Everything else constant, switching from non-exporting to exporting, increases the likelihood of EI adoption by 6.3 percentage points. Given the relatively low level of EI adopters in less-advanced countries, the result supports our expectation of a sizeable environmental premium to exports (H1).

What exactly is captured by the *export* dummy variable? The latter does not neither account for any variance in the level of a firm's export activity nor for the direction of exports. In columns (2), (5) and (8) the share of total output exported by each sector, country and year combination is added to analysis for a continuous relation (*export intensity*). The coefficient is insignificant, both in the full sample regression as well as in the split regression for firms from advanced European countries. Interestingly, we observe in the less-advanced countries again a highly significant relationship between the firm's export activity and the decision to adopt EI.

The specifications in columns (3), (6) and (9) include insights on the role of foreign market's demand for environmental quality in firms' EI adoption decision. In line with H2, *export (EPS top 10)* is positively significant in the full sample. The split reveals that firms based in advanced European countries drive the result. This suggests that there is also an environmental benefit from exports to environmental demanding markets, if the domestic level is already relatively high. There is no significance reported for the less-advanced countries, which describes that there is no additional boost to EI adoption rates if exports are directed to countries with a high demand for environmental quality compared to all other exports.

Another interesting point is the direction of exports is that no country group reports a significantly effect from increasing its export share to emerging countries. First, this approves the role of foreign stakeholders preferences since there is no additional push to uptake the firm's environmental performance (H2), second this contradicts the idea that exporters are less likely to conduct environmental abatement, when serving foreign markets with comparatively low levels of environmental demand. The finding indicates that domestic stakeholders and other more environmental demanding foreign stakeholders, determine the firm's minimum environmental consideration in production.

What can we conclude about the mechanism from our findings on our four measures of firms' export activity? In less-advanced countries, we observe a destination independent step-up of firms' environmental performance in line to the revealed technology uptake by Bustos (2011). We do not observe an additional environmental premium of exports towards environmentally demanding countries. Since countries covered in the variable *EPS top 10* are generally equipped with a high level of environmental know-how, trade

induced knowledge flows and learning-by-exporting might not be the driving forces in firms' EI adoption decision. Accordingly, we conclude that general export related standards and competition pushes firms to cross the hurdle of EI adoption - independent of export destination - and that at this point in time, foreign market's idiosyncrasies play a minor role.

Conversely in advanced countries, a step-up to foreign markets standards is only observable if the firm serves environmental demanding countries. A possible explanation is that firms from advanced countries already face relatively tight EPS, are domestically well-placed to take on skilled workers and state-of-the-art technology.

The regression analysis provides also insights, beyond examining the firm's export performance. Being a multinational company significantly increases the likelihood of EI adoption. Accordingly, *MNCs* are 4.2 percentage points more likely to report that their innovation has a positive effect on the environment. Another important driver for all country groups is external cooperation, internal *R&D* and *subsidies*. The magnitude of the relationship is generally stronger for less-advanced countries and *subsidies* are even no determinant at all in advanced countries, a result confirming the importance of external knowledge and country heterogeneity (De Marchi, 2012; Horbach, 2016). Moreover, firms based in the latter, facing higher environmental regulation, proxied by *emission intensity*, are significantly more environmentally innovative. In the full sample regression and for the group of less-advanced countries, no significance is detected. This indicates that any regulatory pressure on polluting sectors to adopt EI, is only relevant in countries with a generally higher level of environmental awareness. However, we conclude that in less-advanced countries is less willingness to increase regulation on sectors with high emissions per unit of output, instead value creation with implications for job creation seems to remain in the spotlight.

A last finding is that a higher total turnover only increases the likelihood of EI adoption in less-advanced countries.

4.2 Firm's export activity and the breadth of EI adoption

Our second stage limits the sample to firms which have adopted at least one EI. Table 5 depicts the regression results. The separation of country groups in each column is similar to our first stage.

In line to Ghisetti et al. (2015), we find for the full sample regression a highly significant and negative correlation between exports and the number of EI typologies adoptions. Our split of firms based in Europe's advanced countries reports a similar result. This indicates that, in general, that domestic market's idiosyncrasies determine the firm's environmental performance, rather than export activity. However, we take the result with caution, because our *export* variable does neither account for the direction nor for the

Table 5: Hurdle negative binomial estimation results (zero-truncated negative binomial part)

| VARIABLES | Dependent variable: EI typologies adopted | | | | | | | | |
|---------------------------------|---|----------------------|----------------------|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|
| | (1) All | (2) All | (3) All | (4) GDP - High | (5) GDP - High | (6) GDP - High | (7) GDP - Low | (8) GDP - Low | (9) GDP - Low |
| Export | -0.050*** (0.014) | -0.051*** (0.014) | -0.051*** (0.014) | -0.066*** (0.016) | -0.066*** (0.016) | -0.066*** (0.016) | -0.009 (0.025) | -0.008 (0.025) | -0.013 (0.025) |
| Export intensity | | 0.149** (0.070) | | | 0.080 (0.070) | | | 0.266** (0.121) | |
| Export (EPS top 10) | | | 0.359*** (0.098) | | | 0.253** (0.101) | | | 0.608*** (0.167) |
| Export (emerging) | | | 0.100 (0.159) | | | -0.204 (0.190) | | | 0.382 (0.263) |
| MNC | -0.001 (0.013) | -0.002 (0.013) | -0.001 (0.013) | -0.003 (0.015) | -0.004 (0.015) | -0.004 (0.015) | -0.005 (0.024) | -0.007 (0.024) | -0.003 (0.024) |
| Ext. coop. breadth | 0.003 (0.007) | 0.003 (0.007) | 0.003 (0.007) | -0.003 (0.007) | -0.003 (0.007) | -0.003 (0.008) | 0.026 (0.017) | 0.027 (0.017) | 0.029* (0.017) |
| Ext. coop. breadth ² | 0.006*** (0.001) | 0.006*** (0.001) | 0.006*** (0.001) | 0.006*** (0.001) | 0.006*** (0.001) | 0.007*** (0.001) | 0.003 (0.003) | 0.003 (0.003) | 0.003 (0.003) |
| R & D | 0.096*** (0.013) | 0.096*** (0.013) | 0.096*** (0.013) | 0.100*** (0.017) | 0.100*** (0.017) | 0.100*** (0.017) | 0.089*** (0.021) | 0.090*** (0.021) | 0.091*** (0.021) |
| Subsidies | -0.007 (0.011) | -0.007 (0.011) | -0.006 (0.011) | -0.020* (0.012) | -0.020* (0.012) | -0.018 (0.012) | 0.051** (0.021) | 0.049** (0.022) | 0.049** (0.022) |
| (ln) turnover | 0.050*** (0.006) | 0.050*** (0.006) | 0.050*** (0.006) | 0.047*** (0.008) | 0.047*** (0.008) | 0.047*** (0.008) | 0.059*** (0.005) | 0.059*** (0.005) | 0.058*** (0.004) |
| (ln) emission intensity | 0.005 (0.012) | 0.003 (0.013) | 0.003 (0.013) | 0.004 (0.015) | 0.004 (0.015) | 0.003 (0.016) | -0.011 (0.016) | -0.013 (0.016) | -0.011 (0.017) |
| Observations | 15,872 | 15,872 | 15,872 | 11,316 | 11,316 | 11,316 | 4,556 | 4,556 | 4,556 |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Pseudo R ² | 0.0219 | 0.0220 | 0.0222 | 0.0199 | 0.0199 | 0.0200 | 0.0264 | 0.0267 | 0.0273 |
| Prob > Chi ² | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Log Pseudol. | -33,667 | -33,663 | -33,657 | -24,186 | -24,185 | -24,183 | -9,452 | -9,450 | -9,444 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

magnitude of exports. Controlling for the magnitude of trade, *export intensity*, does not reveal any significant negative effect and the sign even turns positive. In less-advanced countries, we do not find any significance of our *exports* dummy, but *export intensity* is positive significant at the five-percent level. In words, exporters show a wider portfolio of different EI typologies adopted, which further backs our first hypothesis.

Our focus on foreign market’s idiosyncrasies in columns (3), (6) and (9) underscores the importance of stakeholders preferences in the firm’s decision on different EI typologies adoption. The result is consistent over all country groups and strongly supports H2. Conversely to the EI adoption phase, the magnitude of the environmental premium is higher for firms based in less-advanced countries, typically facing less domestic pressure for an environmental uptake. Moreover, the magnitude of *export (EPS top 10)* exceeds the the magnitude of *export intensity*. This illustrates that at the stage of adoption of different EI typologies, foreign market’s idiosyncrasies particularly determine the firm’s environmental performance.

Similar to our first stage, we do not observe any significant negative environmental effect for exports to emerging countries, further fostering our claim that foreign stakeholders preference determine firms’ production decision and that firms remain to satisfy environmental demanding foreign as well as domestic stakeholders.

What can we learn on the mechanism of firms’ export activity and EI adoption in our second model? The results strongly back H1 and H2, firms based in less-advanced countries environmentally benefit from export activity, while firms from advanced countries are not required to step-up to foreign markets standards or generally benefit from trade induced knowledge flows. However, firms from advanced countries step-up their environmental performance if they serve highly environmentally demanding markets, a finding similarly observable in less-advanced countries. Exports to emerging countries boost in no specification the breadth of firms’ EI portfolio. Concluding, the revealed role of foreign market’s idiosyncrasies emphasises that firms from all countries incorporate foreign stakeholders demand for environmental quality in their production decision.

MNC is not significant in any specification. We can conclude that while *MNC* may co-determine initial EI adoption i.e. the likelihood that the firm crosses the EI adoption hurdle, it does not induce any change in the breadth of EI adoptions undertaken by an individual firm. Benefits to external cooperation in the EI adoption process drive the breadth of the EI-portfolio in all country groups, however, the effect is non-linear. The marginal effects reveal that similar to the earlier result for the variable capturing initial EI adoption, the magnitude for the external cooperation variable is stronger for firms in less-advanced countries.¹⁵ This is also the case for *subsidies*, although, the positive pattern for subsidies is only observed for firms within the less-advanced country group. For all country groupings, *R&D* and turnover are positively associated with the number

¹⁵See appendix.

of EI typology adoptions. Conversely, sectoral emissions intensity does not determine the number of EI typology adoptions in any model specification.

All in all, both stages of the hurdle negative binomial regression widely confirm our two hypotheses on trade and EI adoption. The interface of the firm's export activity and its environmental performance differs with home country's and foreign market's idiosyncrasies.

Controlling for general effects of firms' export activity, we find export activity boosts firms' decision to adopt any EI in Europe's laggard countries. In the EI adoption phase, exporting helps firms independently of the export destination country to improve their environmental performance. However, exports to environmental demanding countries boost the firm's decision to adopt a wider portfolio of different EI typologies. Firms from advanced countries are both, more likely to adopt any EI and more likely to adopt a higher number of different EI typologies. Interestingly, there is no negative environmental premium observable if a higher share of exports serves emerging countries in all country groups. The results on the role of direction of trade are consistent with a regulation-push and demand-pull induced by foreign stakeholders preferences.

The following part critically evaluates our main results by several robustness checks.

4.3 Robustness

The number of export destinations included in *export* (*EPS top 10*) is admittedly an arbitrary measure. As such, we check the tolerance of the EPS measure, as we vary the regulation-threshold for the number of export destinations admitted into it. Table 6 depicts the results obtained if the number of countries included in our EPS measure varies from 1 to 20, keeping our covariate specification unchanged. The first three columns report our results for the EI adoption outcomes and columns (4) to (6) the results for the number of EI typologies adopted. For each specification, we include estimates for the full sample, high- and low-GDP regression splits, respectively.

First of all, our results remain robust for different definitions of *EPS* (*top 10*). However, the robustness check reveals some additional interesting patterns. A key observation are comparably high standard errors and a wide lack of statistical significance for specification including low numbers of export destinations. The index behaves less noisily and more consistently from *EPS* (*top 5*) onwards. We take from this that a sum of exports to environmental demanding countries is needed to affect firms' decisions of EI adoption.

Interestingly, the exports towards Germany in 2006 and towards Japan in 2012 are added in the variable *EPS* (*top 5*), which is the turning point for a significant effect in four out of six specifications. Both Germany and Japan represent two trade heavyweights with a strong technological bias. Accordingly, exporters to both Germany and Japan are faced with strong stakeholders preferences, which significantly drive our conclusion that

Table 6: Environmental innovation and environmental policy stringency (EPS) in export markets

| VARIABLES | Dependent variable: Adoption of any EI | | | Dependent variable: EI typologies adopted | | |
|---------------------|--|---------------------|-------------------|---|---------------------|---------------------|
| | (1) All | (2) GDP - High | (3) GDP - Low | (4) All | (5) GDP - High | (6) GDP - Low |
| Export (EPS top 1) | 1.736 (2.060) | 1.201 (2.456) | 1.210 (3.705) | 1.247*** (0.395) | 0.826* (0.494) | 1.189* (0.687) |
| Export (EPS top 2) | 0.679 (1.997) | 0.776 (2.279) | -1.436 (3.387) | 0.913** (0.421) | 0.407 (0.510) | 0.878 (0.671) |
| Export (EPS top 3) | 1.133 (0.936) | 1.056 (0.872) | -1.353 (2.937) | 0.419 (0.314) | 0.179 (0.253) | 1.093 (0.669) |
| Export (EPS top 4) | 0.567 (0.517) | 0.652 (0.493) | -2.298 (2.060) | 0.145 (0.181) | 0.100 (0.161) | 0.717 (0.597) |
| Export (EPS top 5) | 1.183*** (0.372) | 1.269*** (0.405) | 0.850 (0.659) | 0.219** (0.094) | 0.131 (0.094) | 0.653*** (0.218) |
| Export (EPS top 6) | 1.128*** (0.376) | 1.095*** (0.411) | 0.867 (0.604) | 0.340*** (0.103) | 0.234** (0.103) | 0.596*** (0.204) |
| Export (EPS top 7) | 1.122*** (0.370) | 1.076*** (0.404) | 0.885 (0.603) | 0.343*** (0.103) | 0.236** (0.102) | 0.607*** (0.205) |
| Export (EPS top 8) | 1.012*** (0.323) | 1.020*** (0.376) | 0.760 (0.480) | 0.356*** (0.098) | 0.263** (0.104) | 0.632*** (0.169) |
| Export (EPS top 9) | 1.007*** (0.325) | 0.596*** (0.225) | 0.737 (0.472) | 0.345*** (0.096) | 0.250** (0.103) | 0.602*** (0.161) |
| Export (EPS top 10) | 0.884*** (0.328) | 0.840** (0.399) | 0.715 (0.455) | 0.359*** (0.098) | 0.253** (0.101) | 0.608*** (0.167) |
| Export (EPS top 11) | 0.561* (0.306) | 0.618 (0.377) | 0.662 (0.432) | 0.234*** (0.087) | 0.224** (0.088) | 0.437*** (0.135) |
| Export (EPS top 12) | 0.507* (0.302) | 0.501 (0.372) | 0.681 (0.428) | 0.259*** (0.085) | 0.273*** (0.093) | 0.428*** (0.133) |
| Export (EPS top 13) | 0.507 (0.317) | 0.462 (0.389) | 0.718 (0.449) | 0.266*** (0.084) | 0.272*** (0.091) | 0.444*** (0.128) |
| Export (EPS top 14) | 0.381 (0.339) | 0.483 (0.369) | 0.506 (0.477) | 0.263*** (0.085) | 0.269*** (0.091) | 0.433*** (0.137) |
| Export (EPS top 15) | -0.081 (0.328) | -0.144 (0.394) | 0.117 (0.427) | 0.231** (0.099) | 0.170* (0.096) | 0.411** (0.167) |
| Export (EPS top 16) | -0.057 (0.312) | -0.061 (0.373) | -0.004 (0.438) | 0.253*** (0.093) | 0.163* (0.096) | 0.490*** (0.142) |
| Export (EPS top 17) | -0.115 (0.319) | -0.087 (0.366) | -0.124 (0.482) | 0.243*** (0.093) | 0.150 (0.097) | 0.478*** (0.143) |
| Export (EPS top 18) | -0.145 (0.317) | -0.107 (0.363) | -0.171 (0.496) | 0.237** (0.093) | 0.149 (0.097) | 0.466*** (0.144) |
| Export (EPS top 19) | -0.169 (0.302) | -0.235 (0.335) | -0.038 (0.447) | 0.224** (0.094) | 0.129 (0.104) | 0.434*** (0.136) |
| Export (EPS top 20) | -0.154 (0.292) | -0.208 (0.327) | -0.061 (0.440) | 0.208** (0.093) | 0.110 (0.103) | 0.425*** (0.135) |
| Observations | 25,942 | 16,535 | 9,407 | 15,872 | 11,316 | 4,556 |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes |

Columns (1) to (3) logit part and columns (4) to (6) zero-truncated negative binomial part
Standard errors in parentheses

Coefficients of independent variables are not reported: Export, MNC, ext. coop. breadth, ext. coop. breadth², subsidies, (ln) turnover, (ln) emission intensity, export (emerging)

*** p<0.01, ** p<0.05, * p<0.1

regulation-push and demand pull boost EI.

The robustness check further illustrates that the positive effect of the EPS steadily dilutes as stringency threshold is varied in advanced countries, allowing more countries to get added to the EPS. If we add more than ten export destinations to our specification, the positive boost of exporting on firm's likelihood to adopt any EI dilutes completely. At the stage of the firm's decision to extend the number of EI adoptions, a similar pattern of a diluting effect of the EPS is observable and there is no significant boost of exports observable if we include more than 16 countries.

In less advanced countries, the robustness check echoes our finding that firms are none reliant on the export destination's country EPS when deciding to adopt any EI. At the stage of the firm's decision to extend the number of EI adoptions, the environmental

premium does not vanish. This observation matches our prior result of an environmental beneficial effect of exports activity, which is widely independent of destination. However, we also back our result that the premium is the highest for export towards environmental high demanding countries, while there is no premium for exports towards emerging countries.

As another robustness check, it is helpful to draw comparisons between our findings and those of the benchmark Horbach (2016) study, by splitting the sample into Eastern and Western Europe, rather than by the level of development. Employing a east/west definition means that with Estonia and the Czech Republic, two relatively advanced Eastern European countries enter into the group of less-advanced countries. Table 7 reports the results applying the definition.

Again, our main results are robust. However, some remaining differences are worth mentioning. In contrast to our findings using wealth criteria to split our regressions, *EPS (top 10)* is also positive significant increasing the likelihood of EI adoption in Eastern countries. However, the effect is only significant at the ten-percent level, while *export intensity* stays the main driver. This backs our first hypothesis, since Eastern European firms benefit relatively stronger from increased export activity compared to Western European firms. In our second specification, we observe some interesting differences in the results. *Export intensity* turns slightly significant in Western countries and loses significance in Eastern countries. This indicates that firms from Estonia and Czech Republic do not environmentally benefit from export activity. However, positive significance of our proxy for stakeholders demand, *EPS (top 10)*, underscores our finding that the direction of trade matters (H2). Additionally, our result of a missing boost by exports to emerging countries stays robust in all specifications and additionally backs H2.

Furthermore, the robustness check highlights the differences of key determinants between country groups, namely *MNC*, the external cooperation and *subsidies*. All measures are significantly more important for firms from Eastern Europe.

5 Discussion

We investigate the relation of a firm's export activity and the decision to adopt environmental innovation (EI) as well as the firm's decision to extend its number of EI typologies. Our empirical investigation employs a merged data set, including firm-level data from two waves of the Community Innovation Survey (CIS) and sector-level data from the World Input-Output tables. Moreover, we calculated, based on the environmental policy stringency index (EPS) of the OECD, a proxy on the demand for environmental quality in the firm's export market. The final data set enables us to provide a novel perspective to the established literature on the determinants of firms' EI adoption, which is a crucial component towards a circular economy. First, we account for country heterogeneity by a

Table 7: Environmental innovation and geographic origin of exporters (east-west definition)

| VARIABLES | Dependent variable: Adoption of any EI | | | | | | Dependent variable: EI typologies adopted | | | | | |
|---------------------------------|--|-------------|-------------|-------------|-------------|-------------|---|-------------|-------------|--------------|--------------|--------------|
| | (1) West | (2) West | (3) West | (4) East | (5) East | (6) East | (7) West | (8) West | (9) West | (10) East | (11) East | (12) East |
| Export | 0.105* | 0.106* | 0.110* | 0.261*** | 0.262*** | 0.255*** | -0.063*** | -0.064*** | -0.062*** | -0.021 | -0.020 | -0.024 |
| | (0.063) | (0.063) | (0.062) | (0.078) | (0.077) | (0.076) | (0.018) | (0.018) | (0.018) | (0.023) | (0.023) | (0.022) |
| Export intensity | | -0.122 | | | 0.688** | | | 0.105* | | | 0.139 | |
| | | (0.230) | | | (0.334) | | | (0.064) | | | (0.104) | |
| Export (EPS top 10) | | | 1.431** | | | 0.650* | | | 0.564*** | | | 0.400*** |
| | | | (0.670) | | | (0.385) | | | (0.143) | | | (0.125) |
| Export (emerging) | | | -1.733 | | | -0.236 | | | -0.153 | | | 0.185 |
| | | | (1.099) | | | (0.730) | | | (0.251) | | | (0.222) |
| MNC | 0.155** | 0.156** | 0.155** | 0.192*** | 0.190*** | 0.194*** | -0.002 | -0.003 | -0.003 | -0.013 | -0.014 | -0.012 |
| | (0.076) | (0.076) | (0.075) | (0.071) | (0.070) | (0.071) | (0.016) | (0.016) | (0.016) | (0.021) | (0.021) | (0.021) |
| Ext. coop. breadth | 0.267*** | 0.267*** | 0.265*** | 0.333*** | 0.335*** | 0.334*** | -0.005 | -0.005 | -0.006 | 0.018 | 0.018 | 0.018 |
| | (0.065) | (0.065) | (0.066) | (0.054) | (0.053) | (0.054) | (0.009) | (0.009) | (0.009) | (0.011) | (0.011) | (0.011) |
| Ext. coop. breadth ² | 0.004 | 0.004 | 0.005 | -0.021** | -0.021** | -0.021** | 0.007*** | 0.007*** | 0.007*** | 0.004** | 0.004** | 0.004** |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| R & D | 0.278*** | 0.278*** | 0.277*** | 0.320*** | 0.317*** | 0.319*** | 0.085*** | 0.084*** | 0.083*** | 0.117*** | 0.117*** | 0.118*** |
| | (0.056) | (0.056) | (0.056) | (0.074) | (0.074) | (0.074) | (0.018) | (0.018) | (0.017) | (0.021) | (0.021) | (0.021) |
| Subsidies | 0.019 | 0.019 | 0.024 | 0.383*** | 0.380*** | 0.385*** | -0.019 | -0.019 | -0.015 | 0.023 | 0.022 | 0.022 |
| | (0.062) | (0.062) | (0.063) | (0.057) | (0.057) | (0.058) | (0.014) | (0.014) | (0.014) | (0.019) | (0.019) | (0.019) |
| (ln) turnover | -0.056 | -0.056 | -0.056 | 0.136*** | 0.135*** | 0.136*** | 0.042*** | 0.043*** | 0.043*** | 0.063*** | 0.063*** | 0.063*** |
| | (0.051) | (0.051) | (0.051) | (0.014) | (0.014) | (0.014) | (0.010) | (0.010) | (0.010) | (0.006) | (0.006) | (0.006) |
| (ln) emission intensity | 0.106* | 0.107* | 0.119* | 0.028 | 0.015 | 0.033 | -0.008 | -0.007 | 0.001 | -0.004 | -0.006 | -0.006 |
| | (0.061) | (0.059) | (0.062) | (0.048) | (0.050) | (0.047) | (0.016) | (0.015) | (0.015) | (0.014) | (0.014) | (0.014) |
| Observations | 12,630 | 12,630 | 12,630 | 13,312 | 13,312 | 13,312 | 8,578 | 8,578 | 8,578 | 7,294 | 7,294 | 7,294 |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Pseudo R ² | 0.0695 | 0.0696 | 0.0702 | 0.177 | 0.177 | 0.177 | 0.0158 | 0.0158 | 0.0161 | 0.0263 | 0.0263 | 0.0267 |
| Prob > Chi ² | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Log Pseudol. | -7,374 | -7,374 | -7,369 | -7,544 | -7,540 | -7,542 | -18,566 | -18,565 | -18,560 | -15,063 | -15,062 | -15,057 |

Columns (1) to (6) logit part and columns (7) to (12) zero-truncated negative binomial part

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

split of our sample of 14 European countries into advanced and less-advanced countries. And second, we account for foreign export market's idiosyncrasies in determining firms' EI adoption, such as foreign stakeholders demand for environmental quality.

We summarise our main finding as follows - firms based in less-advanced countries environmentally benefit from export activity, while firms based in advanced countries only environmentally benefit from exports to environmentally demanding countries.

In more detail, we find that exporters from less-advanced countries produce environmentally more efficient compared to non-exporters. In the firm's decision to adopt any EI, the positive effect is destination independent. There is no particular boost by exports to environmental demanding or emerging countries. This finding indicates that export standards and competition rather than stakeholders preferences explain the adoption of at least one EI. However, we observe a step-up to the mark in the firm's decision to increase the number of EI typologies adopted. Besides a general environmental premium of the firm's export activity, exports towards environmental demanding countries increase the number of EI typologies adopted. Again, there is no effect of exports towards emerging countries.

Firms in advanced countries are already surrounded by domestic stakeholders demand for environmental quality and are in a position to gain access to many sources of local knowledge, state-of-the-art technology and a skilled-labour force. This explains prior results on the topic and our result that there is only an environmental premium of the firm's export activity, if firms serve environmental demanding countries, which are also more likely at the technology frontier of an environmental friendly production.

All in all, our finding of an export destination dependent environmental premium in both country groups is consistent with a foreign policy-push and demand-pull reinforcing positive environmental outcomes. This provides some of the first evidence that firms incorporate foreign stakeholders preferences in their EI adoption decision.

The implications of our findings are several. We structure the discussion around the aspects of policy relevance and relevance for future work.

We first touch on the policy relevance of our findings. The European Union has prioritised the low-carbon economy as one of its four key aspirations. At this point in time, the EU makes distinctions between member states, when mandating how much each state should pay towards upgrading EI from its individual European Regional Development Fund (ERDF) budget. This rate amounts to 15 percent for transition regions and only 12 percent for countries from Europe's poorest member states (European Regional Development Fund, 2019). Yet our findings reveal, it is precisely Europe's poorest member states which are furthest behind, in terms of EI. Perhaps, in the light of our findings, policy makers might reconsider the optimal amount of funding that is earmarked towards regional environmental cohesion e.g. the ERDF.

A second policy-relevant implication has to do with exports. Our findings highlight

the role of exports in transmitting the adoption of green innovation. Given Europe's unique history of integration, culminating in the creation of a single market, a positive environmental effect on production particularly in less-advanced countries, represents one of the hidden benefits arising from closer ties between Europe's member states. A result we argue is explicitly interesting for policy makers in the current time, where trade and multilateralism is internationally under threat.

A welcoming additional step would be for policy makers to facilitate exports e.g. organise trade missions, identify niche markets etc.. But, in so doing, policy makers should be mindful that not foreign markets are created equal. Some markets, such as Scandinavia, France, Canada and Japan impose higher environmental demands on exporters, requiring firms to step-up to the mark, as our title suggests. As such, policy-makers might consider rewarding green tax concessions to exporters that are serving these markets, if exporters can demonstrate the necessity of aligning production to higher environmental standards.

The second strand of implications from our study relates to the possibilities for future work. Building on recent studies in the innovation literature, (Triguero et al., 2013; Ghisetti et al., 2015; Horbach, 2016), we see that framing innovation questions in a multi-country context can tell us more about the country-specific effects that influence innovation, allowing us to generalise policy for a set of similar countries. We argue that new data possibilities e.g. the harmonised Eurostat CIS, broadens the scope for researchers to consider country differences when investigating the diffusions of innovations across countries.

More generally, our findings suggest the usefulness of a more multi-disciplinary approach to innovation. In our case, trade studies provide the impetus for this investigation into exporting and EI adoption. The trade literature emphasises that exports underly learning-by-exporting effects, revenue from foreign sales makes new technology more affordable and increased production enables firms to split fixed costs of emission abatement across more production units (De Loecker, 2007; Bustos, 2011; Forslid et al., 2018). The EI literature builds on the seminal contribution of Rennings (2000) and the revealed double-externality characteristic of EI compared to other innovations. Our study add to the EI literature, while taking insights of both literature strands and shows that country heterogeneity of firms' home country help to explain different conclusions. While our study borrows from the trade literature, other literatures - e.g. environmental or growth economics - may yield equally interesting insights into environmental innovation.

As is usual in any analysis of this kind, we should comment on its limitations. Our data does not allow us to explore, in more depth, the mechanisms by which trade is associated with positive environmental outcomes - foreign consumers or foreign regulation. Arguably these two mechanisms are in some way synonymous, since consumer preferences are embodied in regulation through the voting system (Antweiler et al., 2001). Never-

theless, separating these two mechanisms remains an ambitious goal for future work. A further point worth noting is that our analysis distinguishes between low- and high-GDP countries, but even the low-GDP countries covered in our data are relatively wealthy, on a global scale. Future research might consider including an even wider set of developing countries.

Nevertheless, our findings offer useful insights for policy makers aiming to support the adoption of EI. Data restrictions, up to now, have necessitated a one-size-fits-all approach to EI, neglecting any variation across countries. By relaxing this one-size-fits-all constraint and merging detailed trade data, our study shows that a transition to cleaner production across Europe follows different country-specific trajectories, an observation also valid for the linkage of EI and trade. Additionally, our analysis highlights the fact that the firm's production techniques are largely informed by its domestic and, interestingly, its foreign stakeholders. Most importantly, trade can exert beneficial effects on the environmental performance of Europe's least advanced countries.

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Appendix

Table 8: Is current or expected market demand for environmental innovations a driving factor in decision to introduce innovations with environmental benefits?

| Country | All firms | | Exporters | | Non-exporters | | p-value |
|-----------------|-----------|--------|-----------|--------|---------------|-------|---------|
| | Yes | Total | Yes | Total | Yes | Total | |
| Bulgaria | 28.2% | 1,179 | 33.5% | 738 | 19.5% | 441 | 0.00*** |
| Croatia | 50.2% | 275 | 50.0% | 252 | 52.2% | 23 | 0.58 |
| Cyprus | 55.9% | 59 | 54.3% | 35 | 58.3% | 24 | 0.62 |
| Czech Republic | 26.6% | 1,215 | 28.2% | 1,038 | 16.9% | 177 | 0.00*** |
| Germany | 31.0% | 2,916 | 33.2% | 2,348 | 21.8% | 568 | 0.00*** |
| Estonia | 46.9% | 514 | 47.7% | 482 | 34.4% | 32 | 0.07* |
| Greece | 57.1% | 401 | 56.6% | 327 | 59.5% | 74 | 0.67 |
| Hungary | 52.4% | 813 | 52.3% | 748 | 53.8% | 65 | 0.60 |
| Italy | 29.4% | 1,649 | 31.3% | 1,302 | 21.9% | 347 | 0.00*** |
| Lithuania | 46.7% | 475 | 46.9% | 426 | 44.9% | 49 | 0.39 |
| Latvia | 43.1% | 211 | 43.4% | 198 | 38.5% | 13 | 0.36 |
| Portugal | 40.6% | 3,226 | 42.8% | 2,592 | 31.5% | 634 | 0.00*** |
| Romania | 37.6% | 1,186 | 40.6% | 741 | 32.6% | 445 | 0.00*** |
| Slovak Republic | 41.2% | 417 | 41.3% | 380 | 40.5% | 37 | 0.46 |
| Total | 36.8% | 14,536 | 39.0% | 11,607 | 28.0% | 2,929 | 0.00*** |

Own calculations based on the factors driving enterprise's decision to introduce environmentally beneficial innovations. The CIS 2014 asks respondents to note the degree of importance, while CIS 2008 restricts responses to 'yes' and 'no'. For the CIS 2014, we coded an answer as yes if the degree of importance is high or medium. In Czech Republic only information for 2008 is available. P-values are depicted for a two-sample one-sided t-test. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Description of the dependent and independent variables and their sources

| Variable | Description | Source |
|-------------------------|--|-----------------------------|
| EI | Environmental innovator if at least one of the eight different domains applies (dummy) | CIS |
| EI_num | Number of different environmental innovation adopted (count variable 0-8) | CIS |
| Export | Firm is exporting (dummy) | CIS |
| Export intensity | Share of year/ country/ sector sales exported (lagged) | Dietzenbacher et al. (2013) |
| Export (emerging) | Share of year/ country/ sector sales exported to emerging countries (lagged) | Dietzenbacher et al. (2013) |
| Export (EPS top #) | Share of year/ country/ sector sales exported to top # environmental policy stringent countries (lagged) | Botta and Koźluk (2014) |
| MNC | Affiliation of an international enterprise group (dummy) | CIS |
| R&D | Internal R&D activity (dummy) | CIS |
| Ext. coop. breadth | Number of external cooperation partners involved in the innovation | CIS |
| Subsidies | Firm received public funding for any innovation activity (dummy) | CIS |
| (ln) emission intensity | Logarithm of year/ country/ sector carbon dioxide emission intensity in terms of value added | Eurostat |
| (ln) turnover | Natural logarithm of firm's turnover | CIS |

Table 10: Correlation of dependent and independent variables

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|--------------------------------|-------|-------|-------|-------|-------|------|-------|-------|-------|-------|-------|------|
| (1) EI | 1.00 | | | | | | | | | | | |
| (2) EI_num | 0.75 | 1.00 | | | | | | | | | | |
| (3) Export | 0.14 | 0.12 | 1.00 | | | | | | | | | |
| (4) Export intensity | 0.06 | 0.03 | 0.28 | 1.00 | | | | | | | | |
| (5) Export (EPS top 10) | 0.13 | 0.13 | 0.19 | 0.62 | 1.00 | | | | | | | |
| (6) Export (emerging) | -0.04 | -0.04 | 0.08 | 0.46 | 0.22 | 1.00 | | | | | | |
| (7) MNC | 0.10 | 0.09 | 0.20 | 0.20 | 0.14 | 0.10 | 1.00 | | | | | |
| (8) Ext. coop. breadth | 0.22 | 0.26 | 0.17 | 0.15 | 0.14 | 0.08 | 0.19 | 1.00 | | | | |
| (9) R&D | 0.20 | 0.22 | 0.27 | 0.19 | 0.17 | 0.06 | 0.08 | 0.30 | 1.00 | | | |
| (10) Subsidies | 0.13 | 0.13 | 0.17 | 0.10 | 0.02 | 0.03 | -0.01 | 0.30 | 0.33 | 1.00 | | |
| (11) Turnover | 0.19 | 0.23 | 0.39 | 0.15 | 0.12 | 0.09 | 0.38 | 0.29 | 0.38 | 0.19 | 1.00 | |
| (12) Emission intensity | 0.03 | 0.03 | -0.09 | -0.31 | -0.29 | 0.08 | 0.00 | -0.01 | -0.08 | -0.05 | -0.03 | 1.00 |

Own calculations based on CIS.

Table 11: Summary descriptive statistic of dependent and independent variables

| VARIABLES | (1) N | (2) mean | (3) sd | (4) min | (5) max |
|-------------------------|----------|-------------|-----------|------------|------------|
| EI | 25,942 | 0.612 | 0.487 | 0 | 1 |
| EI_num | 25,942 | 2.527 | 2.678 | 0 | 8 |
| Export | 25,942 | 0.754 | 0.431 | 0 | 1 |
| Export intensity | 25,942 | 0.451 | 0.214 | 0.0146 | 0.980 |
| Export (emerging) | 25,942 | 0.0599 | 0.0507 | 0.000826 | 0.320 |
| Export (EPS top 20) | 25,942 | 0.281 | 0.155 | 0.00526 | 0.807 |
| Export (EPS top 19) | 25,942 | 0.275 | 0.153 | 0.00513 | 0.802 |
| Export (EPS top 18) | 25,942 | 0.255 | 0.146 | 0.00460 | 0.770 |
| Export (EPS top 17) | 25,942 | 0.252 | 0.145 | 0.00457 | 0.764 |
| Export (EPS top 16) | 25,942 | 0.248 | 0.143 | 0.00443 | 0.764 |
| Export (EPS top 15) | 25,942 | 0.229 | 0.136 | 0.00340 | 0.738 |
| Export (EPS top 14) | 25,942 | 0.189 | 0.117 | 0.00273 | 0.681 |
| Export (EPS top 13) | 25,942 | 0.176 | 0.114 | 0.00268 | 0.660 |
| Export (EPS top 12) | 25,942 | 0.168 | 0.112 | 0.00262 | 0.660 |
| Export (EPS top 11) | 25,942 | 0.163 | 0.109 | 0.00213 | 0.658 |
| Export (EPS top 10) | 25,942 | 0.139 | 0.0968 | 0.00203 | 0.543 |
| Export (EPS top 9) | 25,942 | 0.132 | 0.0942 | 0.00201 | 0.537 |
| Export (EPS top 8) | 25,942 | 0.125 | 0.0892 | 0.00201 | 0.535 |
| Export (EPS top 7) | 25,942 | 0.108 | 0.0874 | 0.000575 | 0.533 |
| Export (EPS top 6) | 25,942 | 0.107 | 0.0878 | 0.000554 | 0.533 |
| Export (EPS top 5) | 25,942 | 0.0889 | 0.0789 | 0.000548 | 0.529 |
| Export (EPS top 4) | 25,942 | 0.0539 | 0.0475 | 0.000545 | 0.499 |
| Export (EPS top 3) | 25,942 | 0.0349 | 0.0332 | 0.000452 | 0.311 |
| Export (EPS top 2) | 25,942 | 0.0259 | 0.0231 | 0.000133 | 0.132 |
| Export (EPS top 1) | 25,942 | 0.0223 | 0.0214 | 6.54e-05 | 0.0972 |
| R and D | 25,942 | 0.484 | 0.500 | 0 | 1 |
| MNC | 25,942 | 0.170 | 0.375 | 0 | 1 |
| Ext. coop. breadth | 25,942 | 0.862 | 1.594 | 0 | 7 |
| Subsidies | 25,942 | 0.289 | 0.453 | 0 | 1 |
| (ln) turnover | 25,942 | 15.56 | 2.096 | 7.085 | 24.96 |
| (ln) emission intensity | 25,942 | 5.627 | 1.497 | 2.727 | 8.595 |

Table 12: Environmental policy stringency index

| Year/Country | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|-----------------|------|------|------|------|------|------|------|
| France | 3.28 | 2.86 | 2.90 | 3.69 | 3.15 | 3.70 | 3.57 |
| Denmark | 3.16 | 2.83 | 2.96 | 4.07 | 4.03 | 3.98 | 3.85 |
| Finland | 3.15 | 2.82 | 3.08 | 3.25 | 3.21 | 3.48 | 3.43 |
| Sweden | 3.03 | 2.70 | 2.92 | 3.34 | 3.09 | 3.23 | 3.10 |
| Germany | 3.00 | 2.67 | 2.64 | 3.06 | 3.02 | 3.14 | 2.92 |
| Korea | 2.96 | 2.96 | 3.38 | 3.52 | 3.52 | 3.44 | 2.63 |
| Spain | 2.96 | 2.75 | 2.70 | 3.00 | 2.72 | 2.85 | 2.22 |
| Czech Republic | 2.88 | 2.55 | 2.72 | 2.89 | 2.89 | 2.37 | 2.38 |
| Austria | 2.82 | 2.44 | 2.91 | 3.33 | 3.33 | 3.08 | 2.95 |
| Netherlands | 2.80 | 2.64 | 3.23 | 3.69 | 4.13 | 3.51 | 3.63 |
| Italy | 2.72 | 2.34 | 2.60 | 2.73 | 2.84 | 2.79 | 2.77 |
| Portugal | 2.71 | 2.21 | 2.26 | 2.47 | 2.54 | 2.27 | 2.13 |
| Hungary | 2.59 | 2.30 | 2.55 | 2.66 | 2.77 | 2.68 | 2.63 |
| Belgium | 2.40 | 2.20 | 2.34 | 2.58 | 2.60 | 2.53 | 2.47 |
| United Kingdom | 2.29 | 1.95 | 2.40 | 2.58 | 3.62 | 3.47 | 3.29 |
| Poland | 2.26 | 2.08 | 2.26 | 2.96 | 2.96 | 2.96 | 2.58 |
| Ireland | 2.23 | 1.71 | 2.05 | 2.16 | 2.22 | 2.43 | 2.05 |
| Canada | 2.17 | 3.27 | 3.31 | 3.85 | 3.35 | 3.67 | 3.42 |
| Switzerland | 2.13 | 2.13 | 2.67 | 3.19 | 3.33 | 3.29 | 3.29 |
| Norway | 2.13 | 2.05 | 2.34 | 3.19 | 3.19 | 3.19 | 3.26 |
| United States | 2.13 | 2.34 | 2.47 | 2.93 | 2.68 | 2.47 | 3.17 |
| Australia | 2.01 | 2.01 | 2.26 | 2.69 | 2.50 | 3.34 | 3.72 |
| Greece | 1.84 | 1.92 | 1.83 | 2.08 | 2.33 | 2.33 | 2.13 |
| Slovak Republic | 1.78 | 1.40 | 1.53 | 2.39 | 2.30 | 3.05 | 2.99 |
| Japan | 1.63 | 1.69 | 1.69 | 1.73 | 2.03 | 2.96 | 3.50 |

Description: The OECD Environmental Policy Stringency (EPS) index is a country-specific and internationally-comparable measure of the stringency of environmental policy. Stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour. The index ranges from 0 (not stringent) to 6 (highest degree of stringency). The index covers 28 OECD and 6 emerging countries for the period 1990-2012. The index is based on the degree of stringency of 14 environmental policy instruments, primarily related to climate and air pollution (Botta and Koźluk, 2014). Version: 24.05.2018

Table 13: Hurdle negative binomial estimation results (Logit Part)

| VARIABLES | Dependent variable: Adoption of any EI | | | | | | | | |
|-------------------------|--|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | (1) All | (2) All | (3) All | (4) GDP - High | (5) GDP - High | (6) GDP - High | (7) GDP - Low | (8) GDP - Low | (9) GDP - Low |
| Export | 0.038*** (0.012) | 0.037*** (0.012) | 0.037*** (0.012) | 0.015 (0.012) | 0.015 (0.012) | 0.015 (0.012) | 0.063*** (0.015) | 0.063*** (0.015) | 0.062*** (0.015) |
| Export intensity | | 0.033 (0.053) | | | -0.026 (0.045) | | | 0.180*** (0.064) | |
| Export (EPS top 10) | | | 0.175*** (0.065) | | | 0.166** (0.079) | | | 0.139 (0.088) |
| Export (emerging) | | | -0.085 (0.126) | | | -0.130 (0.140) | | | -0.024 (0.185) |
| MNC | 0.042*** (0.011) | 0.042*** (0.011) | 0.042*** (0.011) | 0.043*** (0.012) | 0.043*** (0.012) | 0.042*** (0.012) | 0.037* (0.019) | 0.036* (0.019) | 0.037** (0.019) |
| Ext. coop. breadth | 0.060*** (0.008) | 0.060*** (0.008) | 0.060*** (0.008) | 0.057*** (0.010) | 0.057*** (0.010) | 0.056*** (0.010) | 0.064*** (0.012) | 0.065*** (0.012) | 0.064*** (0.012) |
| R & D | 0.050*** (0.009) | 0.050*** (0.009) | 0.050*** (0.009) | 0.055*** (0.010) | 0.055*** (0.010) | 0.055*** (0.010) | 0.060*** (0.021) | 0.059*** (0.021) | 0.060*** (0.021) |
| Subsidies | 0.034*** (0.010) | 0.034*** (0.010) | 0.034*** (0.010) | 0.009 (0.010) | 0.009 (0.010) | 0.010 (0.010) | 0.096*** (0.014) | 0.094*** (0.014) | 0.096*** (0.014) |
| (ln) turnover | 0.005 (0.008) | 0.005 (0.008) | 0.005 (0.008) | -0.004 (0.010) | -0.004 (0.010) | -0.004 (0.010) | 0.026*** (0.003) | 0.025*** (0.003) | 0.026*** (0.003) |
| (ln) emission intensity | 0.011 (0.008) | 0.010 (0.008) | 0.012 (0.007) | 0.024*** (0.007) | 0.025*** (0.007) | 0.023*** (0.007) | -0.004 (0.014) | -0.005 (0.015) | -0.002 (0.013) |
| Observations | 25,942 | 25,942 | 25,942 | 16,535 | 16,535 | 16,535 | 9,407 | 9,407 | 9,407 |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Standard errors in parentheses

Average marginal effects are reported

Note: dy/dx for factor levels is the discrete change from the base level

*** p<0.01, ** p<0.05, * p<0.1

Table 14: Hurdle negative binomial estimation results (Zero-truncated negative binomial part)

| VARIABLES | Dependent variable: EI typologies adopted | | | | | | | | |
|-------------------------|---|----------------------|----------------------|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|
| | (1) All | (2) All | (3) All | (4) GDP - High | (5) GDP - High | (6) GDP - High | (7) GDP - Low | (8) GDP - Low | (9) GDP - Low |
| Export | -0.203*** (0.059) | -0.206*** (0.059) | -0.206*** (0.058) | -0.276*** (0.068) | -0.278*** (0.068) | -0.275*** (0.067) | -0.032 (0.096) | -0.032 (0.095) | -0.051 (0.094) |
| Export intensity | | 0.596** (0.280) | | | 0.326 (0.287) | | | 0.998** (0.451) | |
| Export (EPS top 10) | | | 1.435*** (0.389) | | | 1.035** (0.414) | | | 2.282*** (0.616) |
| Export (emerging) | | | 0.399 (0.637) | | | -0.834 (0.778) | | | 1.433 (0.986) |
| MNC | -0.004 (0.051) | -0.010 (0.052) | -0.003 (0.052) | -0.014 (0.062) | -0.017 (0.062) | -0.015 (0.063) | -0.019 (0.090) | -0.024 (0.090) | -0.011 (0.091) |
| Ext. coop. breadth | 0.074*** (0.018) | 0.074*** (0.018) | 0.074*** (0.018) | 0.057*** (0.020) | 0.057*** (0.020) | 0.056*** (0.020) | 0.131*** (0.038) | 0.134*** (0.038) | 0.138*** (0.039) |
| R & D | 0.381*** (0.053) | 0.380*** (0.052) | 0.382*** (0.052) | 0.403*** (0.069) | 0.403*** (0.069) | 0.403*** (0.068) | 0.338*** (0.080) | 0.339*** (0.080) | 0.344*** (0.080) |
| Subsidies | -0.027 (0.045) | -0.029 (0.045) | -0.022 (0.044) | -0.082* (0.049) | -0.082* (0.049) | -0.075 (0.049) | 0.195** (0.082) | 0.186** (0.084) | 0.187** (0.083) |
| (ln) turnover | 0.200*** (0.024) | 0.200*** (0.024) | 0.200*** (0.024) | 0.194*** (0.035) | 0.194*** (0.035) | 0.194*** (0.035) | 0.222*** (0.017) | 0.220*** (0.017) | 0.219*** (0.017) |
| (ln) emission intensity | 0.018 (0.049) | 0.011 (0.051) | 0.012 (0.053) | 0.015 (0.063) | 0.014 (0.063) | 0.013 (0.065) | -0.041 (0.061) | -0.048 (0.062) | -0.042 (0.062) |
| Observations | 15,872 | 15,872 | 15,872 | 11,316 | 11,316 | 11,316 | 4,556 | 4,556 | 4,556 |
| Country dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Standard errors in parentheses

Average marginal effects are reported

Note: dy/dx for factor levels is the discrete change from the base level

*** p<0.01, ** p<0.05, * p<0.1

Data Access

We employed the Community Innovation Survey (CIS) 2008 and 2014. The microdata is restricted in access and usage, but is free of charge. The additional appended data sets are freely available. The World Input-Output Tables can be found at <http://www.wiod.org/home> (Dietzenbacher et al., 2013). The statistics on emission intensity at <https://ec.europa.eu/eurostat/web/environment/emissions-of-greenhouse-gases-and-air-pollutants/air-emission-accounts/database> (Variable: Air emissions intensities by NACE Rev. 2 activity, *env_ac_aeint_r2*).

The detailed process of how to apply for the CIS is described in a pdf document available at https://ec.europa.eu/eurostat/documents/203647/771732/How_to_apply_for_microdata_access.pdf. Key steps are to apply the research organisation to be recognized as a research entity (If not already done before) and to directly apply for the microdata. Both together takes around 12 weeks. If successful, the CD-Roms containing scientific-use files are sent. The data is partially anonymised. However, if needed also non-anonymised data is available in Eurostat's 'Safe Centre' in Luxembourg. More information about the CIS is available at <https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey>. Moreover, we acknowledge the kind support when contacting the Eurostat help-desk.

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