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

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ABSTRACT

We investigate the ability of exports to trigger the adoption of environmental innovation (EI) in firms, shedding light on the determinants of convergence in environmental standards for Europe’s catch-up economies. To analyse this question empirically, we measure the latter as the 1) probability a firm adopts EI and the 2) breadth of EI adoption in firms. Applying Logit and Poisson pseudo-maximum likelihood estimations to firm-level data for 14 European countries, we find that particularly Eastern European exporters report higher EI adoption propensities, an effect exclusively driven by process-based EI and not observable for product-based EI. Additionally, we reveal that regardless of a firm’s origin, exposure to importing countries with high market-related environmental policy stringency, is linked to the adoption of EI. We conclude that learning-by-exporting, regulation-push and demand-pull mechanisms may help to explain these findings, with foreign markets being characterised by a wider diversity of stakeholder preferences.

1. Introduction

The European Green Deal provides a roadmap for a green economic transition and acknowledges that not all member states have the same point of economic departure or have an equal ability to respond to the call for carbon minimising and climate-resilient production (European Commission 2019). This lack of convergence can hinder or even prevent the ability of environmental laggards to negotiate the green transition. But European countries are linked by trade. This raises the following question – to what extent can trade facilitate the green transition and ultimately assist environmental convergence?

A key ingredient towards achieving a green economy is the adoption of environmental innovation (EI) by firms (de Jesus and Mendonça 2018). We analyse how a firm’s export activity relates to EI adoption and whether exports assist firms in Europe’s catch-up economies to step-up to a more environmentally friendly way of producing goods. We expect that learning-by-exporting is particularly important for
firms in Europe’s catch-up economies (De Loecker 2007; Keshminder and Del Río 2019), since EI adoption requires firms to capture knowledge sources beyond those currently available to a firm (De Marchi 2012).

In addition, EI does not happen in a vacuum. Kirchherr et al. (2018) argue that a lack of regulation prevents the realisation of EI adoption and consumers must push for these changes. Peñasco, Del Río, and Romero-Jordán (2017), Newman et al. (2018) and Keshminder and Del Río (2019) claim that with export activity, the set of a firm’s stakeholders also includes foreign stakeholders. If these stakeholders require that firms produce more sustainably, firms respond by increasing their social and environmental performance. We apply this mechanism to EI adoption and expect that exporting firms are exposed to the regulatory and consumer preferences of the countries with which they trade. Accordingly, we expect that trading with foreign markets characterised by stringent environmental demands, can help firms to close the gap in EI adoption rates.

A number of studies have investigated the motives for firms to adopt EI, including examining the link between the internationalisation of firms and their decision to adopt EI (Cainelli, Mazzanti, and Montresor 2012; De Marchi and Grandinetti 2012; Antonietti and Marzucchi 2014; Chiarvesio, Marchi, and Maria 2015; Del Río, Peñasco, and Romero-Jordán 2016; Peñasco, Del Río, and Romero-Jordán 2017; Keshminder and Del Río 2019). We contribute to the understanding of the link between firm’s EI adoption and internationalisation by employing a multi-country setting to analyse whether trade-related knowledge flows, regulation-push induced by environmental policy stringency (EPS) in different export markets and demand-pull by foreign stakeholders, connect to the firm’s decision to adopt and intensify its EI effort.

In our empirical analysis, we use firm-level data for 14 European economies, characterised by different regulatory regimes and stakeholder preferences. Specifically, we follow Horbach (2016) and focus in an alternative specification on the more homogeneous subset of Eastern European countries. Empirically, we apply a Logit estimation to estimate EI adoption rates and a Poisson pseudo-maximum likelihood estimation to estimate the breadth of EI adoption. Specifically, we use data from two appended waves of the Community Innovation Survey (CIS), supplemented with information from the World Input-Output Database (WIOD). The OECD EPS index, split by market-related and non-market-related EPS, is denoted by a continuous variable that captures both exposure to foreign regulation as well as demand for environmental quality by foreign stakeholders (Botta and Kožluk 2014).

We find that exposure to market-related EPS, via exports that over-proportionally target countries with more stringent environmental policies, is associated with generally higher EI adoption rates. Interestingly, our key result for EPS is not consistently observable for non-market-related EPS. Our intuition for this finding is as follows – exposure to market-related EPS, helps to unlock the potential for green demand and affects competition, forcing firms to adopt cleaner processes and products (Peñasco, Del Río, and Romero-Jordán 2017).

In contrast to prior studies on a firm’s export activity and EI adoption, which employ single-country data for advanced European countries (Cainelli, Mazzanti, and Montresor 2012; De Marchi and Grandinetti 2012; Chiarvesio, Marchi, and Maria 2015; Peñasco, Del Río, and Romero-Jordán 2017), we find that export activity positively relates to the EI adoption decision of a firm. The effect is strongest for firms that generate the lion’s share...
of revenue in foreign markets, becoming more predominant once the sample gets restricted to Eastern European countries. From the existing literature and our results, we conclude that Eastern European countries are primarily responsible for driving the revealed positive connection between exports and EI adoption. The effect for laggard countries is in line with knowledge flows from West to East and learning-by-exporting effects documented in the literature (De Loecker 2007; Horbach 2016; Keshminder and Del Río 2019).

Interestingly, a split between product- and process-based EI reveals that the relationship between exports and EI adoption is confined to the latter. The differences in findings for process- and product-based EI, hint at a trade-induced technique effect (Antweiler, Copeland, and Taylor 2001; Bustos 2011; Barrows and Ollivier 2021), improving the environmental performance in production and not necessarily the product-side. Our prior results for exposure to market-related EPS and EI adoption are observable for both process- as well as product-based EI. In line with these findings, we argue that although export activity – in itself – seems little connected to product-based EI, exposure to demanding markets goes hand in hand with the production of cleaner products.

Taken together, the trade-related learning-by-exporting, regulation-push and demand-pull mechanisms described above, help laggard countries to shift towards cleaner production and ultimately, a more circular economy (Kirchherr et al. 2018; Keshminder and Del Río 2019). More specifically, our results hint at a hidden environmental dividend from enlargement of the European Union.

We organise our paper as follows. We first introduce the literature on export activity and EI adoption in order to motivate our background theory and testable hypotheses. Next, we introduce the data used in our analysis before defining our econometric strategy. Finally, we conclude with the results for our econometric analyses, robustness checks and the political implications of our findings.

2. Firms’ exports and the adoption of environmental innovation

Around the turn of the millennium, several studies, inspired by the seminal analysis of Copeland and Taylor (1994), investigated the impacts of trade on the environment. Typically, these studies applied country-level or sector-level data to decompose the effects of trade into the technique, composition and scale effect (Antweiler, Copeland, and Taylor 2001; Frankel and Rose 2005).

Over the last decade, new possibilities using firm-level analysis have become a promising tool for analysing questions on trade and the environment (Cherniwchan, Copeland, and Taylor 2017). In the spirit of these firm-level studies, researchers have explored the positive environmental effects of exporting, e.g. on technology adoption, energy efficiency, pollution abatement and CO$_2$ efficiency (Bustos 2011; Batrakova and Davies 2012; Girma and Hanley 2015; Holladay 2016; Richter and Schiersch 2017; Forslid, Okubo, and Ulltveit-Moe 2018; Barrows and Ollivier 2018, 2021). Many of these latter studies are based on the Melitz (2003) model, whereby the better, more efficient firms select into exporting. A common feature of this strand of studies is the focus on a single country. While lacking the country coverage of the aggregate studies, these firm-level studies are able to uncover many sources of heterogeneity at the level of the firm.
The above studies motivate our analysis of exporting and EI. However, in terms of methodology and theory, our analysis connects more closely with the innovation literature. In its conventional sense, EI is understood as an innovation that is novel to the firm and results in a reduction of the environmental impact of consumption or production activities (Kemp and Pearson 2007; Del Río, Peñasco, and Romero-Jordán 2016). Accordingly, the concept of EI goes beyond the aforementioned measures that relate to the environmental efficiency of production. Notably, this definition also applies to EIs whose positive environmental effects are unintended (Ghisetti and Pontoni 2015). We define the measure as process-based EI if the environmental benefit affects how a firm co-ordinates and applies its resources to produce an end-product. Analogously, where the environmental benefit is tied to the product’s end-usage, we categorise the activity as product-based EI. Generally, EI differs from standard innovation due to its double-externality characteristic (Rennings 2000). In line with the difference, the determinants between standard innovation and EI are dissimilar (Horbach 2008; Cainelli, De Marchi, and Grandinetti 2015; Ghisetti, Marzucchi, and Montresor 2015; Del Río, Peñasco, and Romero-Jordán 2016).

Overall, a consensus has emerged around the main determinants of EI adoption, which can be broadly grouped into four clusters. These are market-pull, technology-push, regulation-push and firm specific factors (Horbach 2008; Del Río González 2009; De Marchi 2012; Horbach, Rammer, and Rennings 2012; Kesidou and Demirel 2012; Borghesi, Cainelli, and Mazzanti 2015; Ghisetti and Pontoni 2015; Barbieri et al. 2016; Del Río, Peñasco, and Romero-Jordán 2016; Horbach 2016; Antonioli and Mazzanti 2017; Marzucchi and Montresor 2017). Del Río, Peñasco, and Romero-Jordán (2016) summarise the empirical literature on the drivers of EI and claim that the literature widely omits analysing the drivers of EI versus standard innovation. Similarly under-researched, is the differentiation between different types of EI, the investigation of effects for middle-income countries and the application of a wider econometric toolkit than the standard Logit and Probit estimators to investigate the effects of a firm’s internationalisation on a firm’s decision to adopt EI. While we cover aspects of these literature gaps, our most substantial contribution is to investigate how a firm’s export activity correlates to its decision to adopt EI.

In our first hypothesis, we apply the well-established idea of regulation-push and demand-pull as a vehicle for EI adoption to the context of globalisation. The intuition is that exporters face, not only the rigours of EPS from domestic stakeholders but exporters are also exposed to the possibly more rigorous policy stringency demanded by foreign stakeholders (Peñasco, Del Río, and Romero-Jordán 2017; Newman et al. 2018; Keshminder and Del Río 2019). Regulation is a powerful mechanism to catalyse EI and has been documented by many researchers in the domestic context (Porter and van der Linde 1995; Jaffe and Palmer 1997; Brunnermeier and Cohen 2003; Popp 2005; Horbach 2008; Kesidou and Demirel 2012; Triguero, Moreno-Mondéjar, and Davia 2013; Borghesi, Cainelli, and Mazzanti 2015). In theory, regulation gets wielded by lawmakers to achieve environmental benefits for the public (e.g. waste management directives (de Jesus and Mendonça 2018; Cecere and Corrocher 2016)).

Botta and Kožluk (2014) create an index to denote a country’s EPS, splitting between market-related and non-market policies. By market-related, they consider taxes and charges applied on input or output of a production process. Non-market-
related policies include technology-support policies. We argue that, particularly, market-related EPS connects to a regulation-push and helps to unlock the potential for green demand. Market-related EPS also affects competition, since it is predicated on the scale and hence cost-effectiveness of production. Exporters exposed to these stringent markets are forced to improve their products and processes to improve their competitiveness (Peñasco, Del Río, and Romero-Jordán 2017; Keshminder and Del Río 2019).

But EPS is not created in a political or economic vacuum. Environmental regulation tends to track consumer environmental awareness (Antweiler, Copeland, and Taylor 2001). This may be the reason why, as Kirchherr et al. (2018) argue, two main impediments preventing the realisation of a circular economy are 1) a lack in government regulation and 2) a lack in consumer awareness.

Peñasco, Del Río, and Romero-Jordán (2017) and Keshminder and Del Río (2019) emphasise the importance of foreign demand-pull on a firm’s EI adoption decision. Newman et al. (2018) empirically illustrate how domestic stakeholder preferences are shaped by entry into foreign markets where foreign stakeholders include governments, buyers of intermediates and end-customers. They find that higher demand for sustainability in foreign markets obliges exporters to these markets to bolster their Corporate Social Responsibility activities. We expect that a firm’s decision to adopt EI responds in a similar way to Corporate Social Responsibility, because adoption of process- or product-based EI can reduce the cost of complying with the market-related regulations and risks associated with foreign stakeholders (Antonietti and Marzucchi 2014). On this basis, we theorise that regulation-push and demand-pull from foreign markets – and not only domestic markets – can induce firms to adopt EI. Based on the above argumentation, we can articulate our first research hypothesis as follows:

**Hypothesis 1**: Exposure to more environmentally regulated foreign markets, characterised by high market-related environmental policy stringency, induces firms to improve their environmental processes and to produce cleaner products.

Apart from regulation and the demands of foreign stakeholders, a group of innovation studies investigates the role of external knowledge in triggering EI in firms (Ghisetti, Marzucchi, and Montresor 2015; Marzucchi and Montresor 2017). De Marchi (2012) emphasises that adoption of EI necessitates the search for knowledge sources beyond those currently available to the firm. This reinforced need for knowledge amplifies the role of external knowledge. Specifically, the move to trade with foreign partners, expands the volume of knowledge to exporters and opens new production possibilities e.g. changes the cost-effectiveness of energy efficient and environmentally friendly technologies (Verdolini and Galeotti 2011).

Ghisetti, Marzucchi, and Montresor (2015) corroborate the importance of external knowledge cooperation, revealing that when firms source external knowledge, it boosts their EI adoption activity. External knowledge is particularly important for the adoption of innovations involving an ‘implement and interact’ mode, e.g. end-of-pipe EI (Marzucchi and Montresor 2017).
Ghisetti and Pontoni (2015) argue that export activity might affect a firm’s technology-push, but that the effect of exports on EI adoption decision is indirect, e.g. mediated by an increase in R&D. In contrast to Ghisetti and Pontoni (2015), we see reasons for a direct (non-mediated) relationship between exporting and EI. We base our argument on a seminal learning-by-exporting study conducted by De Loecker (2007). The latter finds that exports induce direct learning-by-exporting benefits for the firm. In particular, firms from European catch-up economies can benefit from learning-by-exporting, being less well-equipped to source critical knowledge from domestic sources (Peñasco, Del Río, and Romero-Jordán 2017; Keshminder and Del Río 2019). Nor are firms from these catch-up countries likely to be equipped with state-of-the-art technology. And in terms of human capital, firms from these catch-up countries are less able to hire workers with cutting-edge environmental expertise.

In line with studies that underscore the importance of applied knowledge in achieving a circular economy (de Jesus and Mendonça 2018), we expect these knowledge deficiencies of Eastern European catch-up economies, hinder them from evolving towards a green economy. In sum, we expect that exports are inextricably linked to the production techniques applied within firms, and by extension, to the need for process-based EI – both of which have important ramifications for the competitiveness of firms and for the general economic shift to a green economy.

Up to now, there is limited evidence that export activity relates to higher EI adoption rates. Cainelli, Mazzanti, and Montresor (2012) analyse several aspects of EI, namely energy and material reduction, CO₂ abatement, as well as accelerated emissions reductions for soil, water and air. However, their results for Italian firms suggest no impact from a firm’s export activities. Similarly, De Marchi and Grandinetti (2012), using data for a sample of Italian firms, discover no significant effects of a firm’s exports on EI adoption. Peñasco, Del Río, and Romero-Jordán (2017) account for a possible selection bias due to a focus on innovative firms. Moreover, their findings reveal that serving foreign markets does not increase the likelihood of a firm becoming an environmental innovator. This lack of evidence is especially interesting in the light of the aforementioned Melitz-based literature and Kafouros et al. (2008) who find that export activity helps to boost the adoption of standard innovation. Chiavvesio, Marchi, and Maria (2015) distinguish between the types of markets firms serve, limiting their analysis to Italian firms, a country that they argue is characterised by relatively high levels of environmental awareness and EPS. They similarly report no impact of exports on the adoption of EI. They conclude there is a need for further research into the relationship between EPS and trade, particularly in countries characterised by low environmental awareness.

In contrast, Keshminder and Del Río (2019) analyse firm-level data of an emerging country, namely Malaysia. Interestingly, they find that export activity positively relates to EI adoption and link the finding to trade related knowledge flows, regulation-push and foreign demand-pull. Unfortunately, it is difficult to generalise from this study, since it relates only to the Chemical sector.

Ghisetti, Marzucchi, and Montresor (2015) highlight the bias in the EI literature towards advanced countries and extend their sample to include several European countries, some of which are Eastern European catch-up economies. Interestingly, they report a positive correlation between exports and the likelihood that a firm adopts any EI. We
suspect differences between the findings of Ghisetti, Marzucchi, and Montresor (2015) and the aforementioned studies for advanced European countries, may have to do with different cross-country elasticities of EI to exports. This conjecture is in line with Horbach (2016), who reveals differences in the determinants of EI between Eastern and Western European countries and uncovers technology flows from Western towards Eastern Europe. In line with this intuition and the findings of Keshminder and Del Rio (2019), we expect that exporters from Europe’s catch-up countries are more likely to benefit from knowledge flows and learning-by-exporting dynamics. Formally, we can express this hypothesis as:

**Hypothesis 2:** In particular, firms in catch-up economies benefit from learning-by-exporting, a relationship reflected in a positive correlation between process-based environmental innovation and exports.

We should note that it is necessary to analyse both Hypothesis 1 and Hypothesis 2 in a multi-country setting, where the role of country-level differences can be explored (Ghisetti, Marzucchi, and Montresor 2015; Horbach 2016). By considering cross-country sources of heterogeneity, we may be able to shed light on the lack of evidence for a connection between exports and EI in the single-country studies.

### 3. Empirical application

We first present the data applied in the analysis before turning to the empirical model we use to test our hypotheses.

#### 3.1. The Community Innovation Survey (CIS)

We use data extracted from the harmonised European Community Innovation Survey (CIS) waves 2008 and 2014, provided by Eurostat, to test our hypotheses.\(^1\) The CIS includes detailed coverage of firm-level information relating to many aspects of innovation: inputs, outputs, sources, effects, obstacles and modifiers (Mairesse and Mohnen 2010). Even if the data comes accompanied by the standard caveats – the responses are self-reported and anonymisation prevents the construction of a standard panel – the CIS has nevertheless proven a useful basis for studies investigating the determinants of EI in firms (Mairesse and Mohnen 2010; Ghisetti, Marzucchi, and Montresor 2015).

Within the harmonised CIS, innovation is defined along the lines of the Oslo Manual, focussing on the firm’s adoption phase rather than the novelty of an innovation (OECD and Statistical Office of the European Communities 2005). This definition allows us to capture knowledge flows that accelerate the catch-up process, whereby firms across Europe, step-up their environmental performance.\(^2\) The CIS waves 2008 and 2014 include an expanded list of EI variables, reporting many forms of the latter. In terms of

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\(^1\)Details about the data access are part of the appendix.

\(^2\)The 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 organisation into the market.
the breadth of environmental variables surveyed – data is collected for nine and ten different measures of EI in the 2008 and 2014 waves, respectively. There are slight differences in the formulation of the questions across the waves.

Our analysis focuses on eight measures of EI (EI typologies), which are repeatedly surveyed in both waves or which can be adjusted to ensure comparability. The end result is five typologies dealing with EI processes and three typologies touching on the firm’s final product. Turning to the process-based measures – these comprise unit reductions in material or water usage recorded by the firm. Also elicited is information about reductions in energy usage or the \( \text{CO}_2 \) footprint (i.e. cuts in total \( \text{CO}_2 \) production). In addition, information is collected on reductions in air, water, noise or soil pollution. Moreover, our final data contain an indicator denoting where a firm has replaced a share of materials with less pollution-intensive or less hazardous substitutes. Lastly, we include information about the extent of recycled waste or inputs used in production. As previously mentioned, we also cover three different product-based EI with environmental benefits. These comprise innovations in product or service after-sales, reductions in negative externalities (e.g. energy waste) and heightened scope for recycling the final product or service.

In line with Ghisetti, Marzucchi, and Montresor (2015) and Mairesse and Mohnen (2010), we focus on firms reporting a product or process innovation during the two survey periods or which could be described as innovation-active. With the exclusion of non-innovative-active firms, we isolate the specific determinants of EI versus standard innovations (Rennings 2000; Horbach 2008; Del Río, Peñaasco, and Romero-Jordán 2016; Ghisetti, Marzucchi, and Montresor 2015).

It is a stylised fact that exporters are, on average, more productive than non-exporters (Melitz 2003). Additionally, exports represent a potential conduit for firms to adopt innovations (Kafouros et al. 2008). Previewing the descriptive statistics, we can confirm this pattern. Among the sub-sample of innovation active firms, 43% claim to have generated some sales abroad. Among non-innovation active firms, the corresponding share is 27%. Since our estimation sample includes only innovators (where export propensity is disproportionately high), we should highlight that any findings for a positive relationship between exporting and innovation represents a lower bound.

Our final estimation sample includes 23,653 observations from seven manufacturing sectors based in 14 European countries. These include Germany, Italy, Cyprus, Greece, Portugal, Czech Republic, Estonia, Slovak Republic, Croatia, Hungary, Latvia, Lithuania, Romania and Bulgaria. Barbieri et al. (2016) exhort researchers to conduct cross-country studies to capture differences across countries, while acknowledging the lack of comprehensive data. Our estimation sample covers a diverse group of countries, e.g. Germany and Italy as representatives of the advanced European economies. Portugal and Greece are more typical of Europe’s Southern economies. Lastly, Cyprus, compared with the other players, is a minor economy. Finally, our data include a comprehensive mix of Eastern European countries. Ghisetti, Marzucchi, and Montresor (2015) exploit a similar sample, referring to the advantages of focusing on such a diverse group of European countries helping to shed light on the motives for firms to adopt EI. Unfortunately, due to

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3The 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, Marzucchi, and Montresor (2015)). Anonymised data of other countries is unfortunately not available.
data availability constraints, our data does not allow complete coverage for the entire continent of Europe. In line with this drawback and our aim to zero in on the economies within Europe where environmental catch-up is most urgent (environmental laggards), we restrict our analysis in alternative specifications to the smaller and more homogeneous subset of Eastern European economies.

The size of the sample differs substantially across the countries covered. However, the harmonised CIS employs a methodology designed to maximise comparability across countries. For instance, the official register of businesses is used for identifying an appropriate sample frame and minimum sample sizes are defined. The resulting coverage allows researchers to draw comparisons across country, sector and year, for firms with at least 10 employees. The next part describes our econometric strategy.

3.2. Econometric strategy

We apply a Logit estimation to test what motivates firms to adopt an EI, where the adopted EI can refer to any of the innovations listed above. In a second step, we apply a Poisson pseudo-maximum likelihood (PPML) estimation in order to analyse the determinants of the number of EIs adopted.

We specify our Logit estimation for a firm $i$, producing in sector $z$, located in country $j$ at time $t$ as:

$$EI_{izjt} = \alpha + \beta_{11}^{\text{exportactivity}}_{it} + \beta_{21,4}^{\text{EPSexposure}}_{zjt} + \beta_{n}^{\text{controls}}_{it} + \gamma_{\text{country}}_{j} + \delta_{\text{sector}}_{z} + \zeta_{\text{year}}_{t} + \varepsilon_{i}$$

(1)

$EI_{izjt}$ is a dummy variable that takes the value one for any of the eight different EIs that get adopted by a firm. In two alternative specifications, we limit the EIs to those characterised as process- or product-based, respectively.

Export activity$_{it}$ is our first covariate of interest, a categorical variable denoting three categories of the firm’s export status. The first category applies if a firm does not serve foreign markets. The second category denotes a firm serving foreign markets but where the bulk of the firm’s sales are generated domestically. The final category, pertains to firms whose sales are predominantly generated in foreign markets. Hence, we can pick up differences in outcome for the firm with changes in the extent to which a firm integrates into foreign markets.\(^4\) Particularly, we might expect some differences in innovation outcomes for firms that are highly reliant on foreign markets. Previous studies have commented on the direction of the relationship between exports and EI. On the one hand, Duchin, Lange, and Kell (1995) and Antonietti and Marzuchi (2014) find that the firm’s adoption of improved production technologies, opens up new export possibilities, even before the firm takes the decision to export. However, the firm might enters a market and following entry, begins adopting EI in response to foreign demand for clean production (De Marchi and Grandinetti 2012). We acknowledge the CIS data is not equipped to deal with reverse causality. However, the data can deliver insights on the EI adoption and exporting, exploiting cross-country differences in the data and controlling for an array of additional covariates. Significantly, in both

\(^4\)The CIS 2014 does also include information on the percent of turnover from sales abroad, however, the data is not available for 2008 and our estimation strategy relies on exploiting both survey periods.
scenarios – EI adoption before and following the decision to export – we expect that country-level idiosyncrasies are powerful co-determinants of the firm’s decision to adopt and intensify its EI adoption.

$\text{EPS}_{\text{exposure}_{jkt}}$ measures a firm’s export exposure towards environmentally demanding markets – our second key area of interest. We distinguish between market-related and non-market related rigorousness in the environmental demand of stakeholders in the export destination. In this way, we can proxy for foreign demand-pull and regulation-push by exploiting the OECD EPS Index (Botta and Koźluk 2014). This index ranges from zero (non stringent) to six (highest degree of stringency) and covers most OECD countries, in addition to six major emerging countries, including the BRICS. The EPS, therefore, provides a reasonably comprehensive coverage of the world’s main economies in international climate policy. Overall, the index captures 14 environmental policy instruments. Nine instruments are market-related and five instruments are non-market related. In contrast to its most commonly applied alternative, pollution abatement cost and expenditure, the EPS index is comparable over time and across countries (Martínez-Zarzoso, Bengoecha-Morancho, and Morales-Lage 2019). In our context, we argue that market-related EPS instruments particularly affect competition, sharpening consumer appetite for green products and processes. This heightened appetite, in turn, might nudge exporters serving these markets to step-up to the respective competition and environmental demands.

We calculate a continuous variable to proxy a firm’s exposure to foreign EPS (Equation 2):

$$\text{EPS}_{\text{exposure}_{jkt}} = \frac{\sum_{k=1}^{n} \sum_{t=1}^{T} \text{EPS}_{k(t-2)} \times \text{exports}_{jzk(t-2)} \times \sum_{k=1}^{n} \text{exports}_{jzk(t-2)}}{\sum_{k=1}^{n} \text{exports}_{jzk(t-2)}}$$

$\text{EPS}_{\text{exposure}_{jkt}}$ is the environmental policy exposure for firms based in country $j$, producing in sector $z$ at time $t-2$, which are the years 2006 and 2012 – both marking the points in time when coverage commenced for the respective CIS survey waves. In line with Botta and Koźluk (2014), we differ between market-related and non-market-related EPS.

The numerator captures the sum of exports of a sector $z$ in country $j$ at time $t-2$ towards the country $k$, the latter weighted by a country’s $k$ share of the sum of EPS scores at time $t-2$. More precisely, $\text{EPS}_{k(t-2)}$ is the OECD EPS index of country $k$ at time $t-2$. $\text{Exports}_{jzk(t-2)}$ capture the exports of sector $z$ in country $j$ at time $t-2$ to country $k$ and $n$ denotes the number of different countries covered in OECD EPS index. Even though we only have EPS information for 31 countries, the overall export coverage is quite comprehensive, covering around 81% of all exports in 2006 and circa 74% of all exports in 2012. The remaining exports are likely to target environmentally lax markets that we would not expect to drive our key results.

The denominator captures the average exports of a sector $z$ in country $j$ at time $t-2$.

In terms of interpretation, any average score in excess of one, indicates that exports are generally targeted towards countries with an above-average EPS score, which is the case for the majority of firms in our sample.
To give a flavour of the magnitude of these weighted exposures – exposure to market EPS ranges between 0.49 and 1.59, with an average score of 1.19. Alternatively, non-market exposure ranges between 0.81 and 1.81, averaging at 1.34.

We now turn our focus to the covariates in our estimation. This choice of covariates echoes a wide set of empirical studies on EI diffusion, referring to technology- and regulation-push, market-pull as well as firm-specific factors (Barbieri et al. 2016).

First, a foreign ownership dummy, MNC, captures another dimension of a firm’s internationalisation. There is strong support for the view that foreign ownership promotes the firm’s environmental performance (Brucal, Javorcik, and Love 2019). However, in terms of EI adoption, the results are mixed. Cainelli, Mazzanti, and Montresor (2012) find that only locally embedded MNC are more likely to adopt EIs, while Peñasco, Del Rio, and Romero-Jordán (2017) do not find that firms with foreign equity are more likely to adopt EIs. Since foreign ownership and exports often go hand in hand, we run an additional robustness check, excluding these multinational firms (Antràs and Yeaple 2014).

Ghisetti, Marzucchi, and Montresor (2015) analyse the role of external knowledge sourcing, adding the breadth of knowledge sources. In the same way, we capture the number of external cooperation partners involved in the innovation progress, ext.coop., additionally including a squared term to account for a potentially non-linear relationship. We further proxy absorptive capacity with a dummy, know-how, to capture whether a firm has acquired existing knowledge from other enterprises or organisation.

A dummy denoting the presence of R&D activity is also included. This is intended to capture a firm’s organisational and technological capabilities (Horbach 2008; Ghisetti and Pontoni 2015). Ultimately, we decided against the inclusion of the R&D intensity and external R&D variable, due to concerns about missing data which would have substantially reduced the sample size. Unfortunately, we cannot distinguish between green and non-green R&D activity. Nevertheless, the R&D dummy still captures a firm’s technology-push, though it is incapable of explaining how specific R&D activities channel into the adoption of EI.

Horbach (2008) shows that subsidies encourage the firm’s decision to adopt EI, even if the subsidies are not targeted towards improving the firm’s environmental performance. Accordingly, we add a dummy subsidies to indicate whether the firm has received any public support for its innovation, subsidies for which must have been received in the 3 years prior to the survey.

Since the CIS does not directly allow us to control for impacts of domestic environmental policy, we follow Antonioli and Mazzanti (2017) and calculate the sector-based average of firms claiming to have adopted EIs in response to environmental regulation, denoted as EPS(home). Since we want to limit the variable to domestic EPS, we exclude exporters from the calculation of the share.5

Next, we include firms’ turnover as a proxy for size ((ln)turnover) as well as year, country and sector-fixed effects. Our key variable of interest capturing foreign EPS, varies at the country-sector level and the inclusion of fixed effects absorbs most of the variation we

5We cannot follow our approach for foreign EPS described above, because not all countries of the CIS sample are covered in the OECD EPS index. Moreover, the OECD measure does not distinguish between sectors. However, our measure sheds light on EPS, in a way not seen so far in previous studies. Our overall approach differs from Ghisetti, Marzucchi, and Montresor (2015), who use carbon dioxide emissions relative to value added as a proxy for domestic EPS. The advantage of our proxy is that it elevates the role of policy makers and does not restrict domestic EPS to CO2 emissions.
are interested in. Accordingly, we run an alternative specification without country-fixed effects to analyse the role of exposure towards environmentally stringent countries (market and non-market). Intuitively, we compare firms from similar sectors from different countries, differing in their exposure to foreign environmental demand and regulation. In line with Horbach (2016), we expect the responsiveness of the innovation outcome to vary with the firm’s home country. In order to account for the particularities of Eastern European countries, we substitute the country-fixed effects in the specifications focusing on foreign EPS with a dummy capturing if a firm is based in Eastern Europe, namely the variable east.6

In a second estimation, our alternative outcome is the breadth of EI, where the latter is measured as the count of EI employed by the firm. Again, we split process-based and product-based EIs, reporting these separately. Since this measure varies between zero and a variety of positive integers (eight, five and three) for total, process- and product-based EI, respectively, we apply a Poisson pseudo-maximum likelihood (PPML) estimation. Our reasoning is that this estimation method is robust in the presence of many zeros, outperforming its alternatives. In addition, we are not required to make any additional assumptions about the distribution, as it would have be the case for truncated models or would have been the case had we taken the logarithm of the count of EIs. Lastly, PPML performs satisfactorily in the presence of overdispersion (Silva and Tenreyro 2006).

Accordingly, our second equation is:

\[ \text{EIbreadth}_{ijt} = \alpha + \beta_{1,2}\text{exportactivity}_{it} + \beta_{3,4}\text{EPSexposure}_{ijt} + \beta_{n,\text{controls}}_{it} + \gamma_{\text{country}}j + \delta_{\text{sector}}z + \zeta_{\text{year}}t + \epsilon_{i} \]

(3)

The inclusion of covariates mirrors the Logit estimation described above. In both specifications \( \epsilon_{i} \) determines the error term, which is clustered at the sector-country level.

In line with Hypotheses 2 and in order to provide insights on differences between Europe’s catch-up process, we run our estimations also for the subgroup of 10,358 Eastern European firms. These are based in Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Romania, and Slovak Republic. We also expect external knowledge sources (cooperation, know-how acquisition) and subsidies to be especially important for firms located in Eastern Europe. Before we commence our empirical investigation, we present some descriptive statistics, providing insights on our variables of interest and the data in general.

### 3.3. Descriptive statistics

Figure 1 illustrates a breakdown of EI adoption split by type of EI and a country’s geography.

Since this study throws the spotlight on EI, it is worth highlighting the breakdowns for this outcome variable, 60.9, 58.4 and 40.3%, for the adoption of total, process- and product-based EI, respectively.7 Overall, the preponderance of non-adopters in all categories motivates our decision to apply PPML, which is the workhorse model in empirical specifications containing many zero-observations. On average, a firm adopts

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6Table A1 includes the summary statistics of the covered variables.

7See appendix for the summary statistics of all variables.
2.52 EIs, 1.74 process-based EIs and 0.78 product-based EIs. The geographic split reveals that Eastern European firms are less likely to report any EI. Here a firm adopts, on average, 2.13 EIs, 1.51 process-based EIs and 0.62 product-based EIs.

We now shed some light on the country heterogeneity in EI adoption rates, the role of demand and regulation in a firm’s decision to adopt EI and differences between exporters and non-exporters. Table 1 reports a country’s EI adoption rates and additionally reports the results for a two-sample, one-sided t-test to evaluate differences between exporters and non-exporters.

Countries have widely differing rates of EI adoption, Portuguese firms positioned at the highest end of the continuum (78.7%). The economically poorest country, Bulgaria, lies at the lower end of the continuum, 27.5%, whereby, only a minority of firms can be seen to adopt EIs during the period.

Interestingly, these descriptive statistics reveal that exporters (65.3%) are significantly more likely to implement any EI compared to non-exporters (47.6%). For Eastern European firms, over half are seen to be EI adopters. Examining this percentage by export status, we see a higher share for exporters than for non-exporters (61.2% vs 37.9%). In the full sample, the difference is also significant, but less pronounced (70.2% vs 63%). But not every country shows a positive association between exporting and adoption rates. Exceptions include Croatia, Germany, Greece, Lithuania and Romania. However, in certain of these countries (Croatia, Greece and Lithuania), issues with sample size urge a cautious approach in inferring any statistical effects from the observed differences.

**Figure 1.** Number of EI typologies adopted split by geographic location.
At the core of Hypothesis 1, is the argument that regulation-push and demand-pull mechanisms by foreign stakeholders induce firms to adopt EIs. Accordingly, Tables 2 and 3 focus on factors reported by EI adopters in motivating their decision to adopt an EI.

### Table 1. Firms implemented any EI separated by geographic location and export status.

| Country            | All firms | Exporters | Non-exporters | p-value |
|--------------------|-----------|-----------|----------------|---------|
|                    | Yes (%)   | Total     | Yes (%)        | Total   | p-value |
| Bulgaria           | 27.5      | 4,281     | 34.5           | 2,138   | 0.01*** |
| Croatia            | 65.6      | 419       | 66.5           | 379     | 0.13    |
| Cyprus             | 40.4      | 146       | 47.9           | 73      | 0.03**  |
| Czech Republic     | 73.4      | 3,032     | 74.8           | 2,587   | 0.01**  |
| Germany            | 73.0      | 2,103     | 73.0           | 1,716   | 0.22    |
| Estonia            | 58.9      | 873       | 59.7           | 809     | 0.01    |
| Greece             | 61.3      | 654       | 61.9           | 528     | 0.25    |
| Hungary            | 67.4      | 1,206     | 68.4           | 1,094   | 0.01**  |
| Italy              | 56.0      | 3,335     | 58.8           | 2,473   | 0.00*** |
| Lithuania          | 63.9      | 743       | 63.6           | 670     | 0.72    |
| Latvia             | 61.0      | 346       | 62.9           | 315     | 0.11    |
| Portugal           | 78.7      | 4,120     | 79.2           | 3,287   | 0.02    |
| Romania            | 65.7      | 1,798     | 66.8           | 1,108   | 0.11    |
| Slovak Republic    | 69.8      | 597       | 71.3           | 533     | 0.01**  |
| Non-Eastern Europe | 68.6      | 10,358    | 70.2           | 8,077   | 0.01**  |
| Eastern Europe     | 54.8      | 13,295    | 61.2           | 9,633   | 0.00*** |
| Total              | 60.9      | 23,653    | 65.3           | 17,710  | 0.00*** |

Own calculations based on 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.

### Table 2. 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   | p-value |
| Bulgaria           | 49.4      | 1179      | 56.4           | 738     | 0.00*** |
| Croatia            | 83.3      | 275       | 82.9           | 252     | 0.69    |
| Cyprus             | 78.0      | 59        | 74.3           | 35      | 0.79    |
| Czech Republic     | 63.3      | 1215      | 63.9           | 1,038   | 0.15    |
| Germany            | 35.1      | 1,491     | 35.5           | 1,214   | 0.24    |
| Estonia            | 64.8      | 514       | 64.8           | 483     | 0.49    |
| Greece             | 76.6      | 401       | 77.7           | 327     | 0.13    |
| Hungary            | 68.1      | 813       | 67.1           | 748     | 0.98    |
| Italy              | 45.6      | 1,717     | 47.7           | 1,343   | 0.72    |
| Lithuania          | 76.2      | 475       | 75.8           | 426     | 0.83    |
| Latvia             | 64.5      | 211       | 63.6           | 198     | 0.11    |
| Portugal           | 64.0      | 3229      | 66.5           | 2,594   | 0.00*** |
| Romania            | 71.5      | 1,182     | 74.1           | 740     | 0.01*** |
| Slovak Republic    | 73.1      | 417       | 73.9           | 380     | 0.11    |
| Non-Eastern Europe | 54.0      | 6,897     | 55.8           | 5,513   | 0.00*** |
| Eastern Europe     | 65.5      | 6,281     | 67.6           | 5,003   | 0.00*** |
| Total              | 59.5      | 13,178    | 61.4           | 10,516  | 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.
Table 3. Is current or expected market demand for EIs a driving factor in decision to introduce innovations with environmental benefits?

| Country         | All firms | Exporters | Non-exporters |
|-----------------|-----------|-----------|---------------|
|                 | Yes (%)   | Total     | Yes (%)       | Total     | Yes (%)       | Total     | p-value |
| Bulgaria        | 28.2      | 1179      | 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      | 1215      | 28.2          | 1038      | 16.9          | 177       | 0.00*** |
| Germany         | 34.7      | 1491      | 37.1          | 1214      | 24.2          | 277       | 0.00*** |
| Estonia         | 46.9      | 514       | 47.6          | 483       | 35.5          | 31        | 0.1*    |
| Greece          | 57.1      | 401       | 56.6          | 327       | 59.5          | 74        | 0.67    |
| Hungary         | 52.4      | 813       | 52.3          | 748       | 53.8          | 65        | 0.6     |
| Italy           | 29.4      | 1649      | 31.3          | 1302      | 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      | 3226      | 42.8          | 2592      | 31.5          | 634       | 0.00*** |
| Romania         | 37.6      | 1182      | 40.8          | 740       | 32.4          | 442       | 0.46    |
| Slovak Republic | 41.2      | 417       | 41.3          | 380       | 40.5          | 37        | 0.46    |
| Non-Eastern Europe | 37.7 | 6,826 | 39.7 | 5,470 | 29.6 | 1,356 | 0.00*** |
| Eastern Europe  | 38.1      | 6,281     | 40.6          | 5,003     | 28.1          | 1,278     | 0.00*** |
| Total           | 37.9      | 13,107    | 40.1          | 10,473    | 28.9          | 2,634     | 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.

The descriptive results are in line with the hypothesis. The majority of all environmentally innovative firms state that environmental regulation and other policy measures have guided their decision to adopt environmentally beneficial innovations. Interestingly, this proportion is significantly higher among exporters than non-exporters (61.4% vs 52%). Zeroing in on the Eastern European firms, this percentage rises even further, with 65.5% reporting that regulation has helped to motivate their adoption of EIs. Among East-European exporters, this share is considerably higher for exporters than non-exporters (67.6% vs 57.5%). These relatively high values suggest that EPS boosts EI, particularly in Europe’s catch-up economies.

Turning from regulation to demand-induced motives for introducing environmental beneficial innovation (Table 3), we can observe a similar pattern between exporters and non-exporters. Approximately 40.1% of the former and 28.9% of the latter state that demand for EI influenced their firm’s behaviour. This difference is again significant. However, for this dimension, the relative shares are quite similar between Eastern European and non-Eastern European countries. Even if the differences for exporters and non-exporters are not significant across all countries, the pattern broadly supports our conjecture that demand by foreign stakeholders helps to motivate the pressure to adopt innovations with environmental benefits.

The descriptive statistics we report above, neither control for additional covariates that would help to motivate EI adoption rates. Nor do they account for the intensity nor destination of exports. For this we turn to the econometric specifications.
4. Results and discussion

We start the discussion of the empirical results, presenting the determinants of EI adoption. This includes reporting our findings for the full sample of countries, before limiting this sample to the smaller and more homogeneous group of Eastern European catch-up economies and repeating the estimations for process- and product-based EI. Finally, we conduct a robustness check, excluding the multinational firms.

4.1. Firm's export activity, environmental policy stringency and EI adoption

Table 4 depicts the results of the estimations on the drivers of EI adoption. Columns 1 to 4 focus on the full sample and columns 5 to 8 restrict the sample to firms based in Eastern Europe. For our alternative measures of the outcome variable (the adoption of any single EI and the breadth of EIs adopted), we apply a Logit and PPML estimation, respectively.

| VAR.          | Logit Full sample | PPML Full sample | Logit East | PPML East |
|---------------|-------------------|------------------|------------|-----------|
| Exporter      | 0.034*** (0.012)  | 0.039*** (0.012) | 0.047*** (0.017) | 0.045*** (0.018) |
| Exp. dom.     | 0.035*** (0.013)  | 0.063*** (0.013) | 0.102*** (0.090) | 0.027*** (0.014) |
| Market EPS    | 0.221*** (0.069)  | 1.717*** (0.439) | 0.156*** (0.060) | 0.925*** (0.342) |
| Non-m. EPS    | 0.223*** (0.078)  | 0.840*** (0.569) | 0.139* (0.083)  | 0.065 (0.455)    |
| MNC           | 0.037*** (0.011)  | 0.388*** (0.012) | 0.179*** (0.051) | 0.083*** (0.052) |
| Ext. coop.    | 0.050*** (0.006)  | 0.191*** (0.023) | 0.218*** (0.022) | 0.053*** (0.007) |
| R&D           | 0.052*** (0.010)  | 0.413*** (0.047) | 0.519*** (0.055) | 0.060*** (0.015) |
| Know-how      | 0.038*** (0.016)  | 0.339*** (0.015) | 0.340*** (0.067) | 0.086*** (0.059) |
| Subsidies     | 0.048*** (0.008)  | 0.171*** (0.044) | 0.055 (0.051)   | 0.071*** (0.011) |
| (In) turn.    | 0.014*** (0.005)  | 0.144*** (0.025) | 0.148*** (0.024) | 0.025*** (0.003) |
| EPS (home)    | 0.090*** (0.035)  | 0.676*** (0.254) | 2.478*** (0.517) | 0.084*** (0.038) |
| East          | −0.106*** (0.027) | −0.774*** (0.059)| 0.055 (0.038)   | 0.258 (0.385)    |

Observations: 23,653 23,653 23,653 23,653 13,295 13,295 13,295 13,295
Country: Yes Yes Yes Yes Yes Yes Yes Yes
Sector: Yes Yes Yes Yes Yes Yes Yes Yes
Year: 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
The first column closely relates to Ghisetti, Marzucchi, and Montresor (2015). In line with their findings, we observe a significant relationship for firms reporting some exports and for the most intensively exporting firms, those firms generating the bulk of their sales in foreign markets. Restricting the sample to Eastern European countries reveals that these catch-up economies strongly drive the correlation. Interestingly, in columns 3 and 7, the export categories lose significance. However, in line with Hypothesis 2, for the catch-up sample (column 7), majority exporters are still significantly more likely to deepen the breadth of their EI. In other words, highly internationalised firms in Eastern Europe report significantly higher EI adoption rates and higher breadth of EI adoption.

Also new to the literature, we find strong and consistent support for Hypothesis 1, that demand of foreign stakeholders for environmental quality (denoted as Market EPS) is a powerful driver of the decision to adopt EIIs. This finding is valid for the full as well as the Eastern European subset. In addition, this finding is robust for alternative definitions of the outcome variable, EI adoption and EI breadth. However, this pattern is less consistent for its sister variable, non-market-related exposure.

Our regression analysis provides additional insights, beyond those arising from export performance. Being a multinational company significantly increases the likelihood of EI adoption. A glance at the marginal effect reveals that MNCs are 3.7 percentage points more likely to report that their innovation exerts a positive effect on the environment. This result is not observable for the breadth of EI in Eastern European countries. Other important drivers (consistent across all country splits) are external cooperation, internal R&D, acquisition of know-how, subsidies, domestic EPS and size. For some of these variables (external cooperation, acquisition of know-how and subsidies), the magnitude of the relationship is stronger for firms in Eastern European countries. These firms have a lower baseline propensity to adopt EI. It may well be that availability of external finance and knowledge may assist these firms to step-up their environmental performance. This interpretation underscores the role of country heterogeneity as a powerful modifier in the context of EI (Horbach 2016).

Next, we split EI into its process- and product-based components, respectively. In line with Hypothesis 2, we expect that particularly export activity relates to process EI. Exposure to market EPS is expected to impact on both components. However, we conjecture the effect of non-market EPS remains limited.

### 4.2. Process vs. product EIIs

The general structure of the columns replicates Table 5 discussed above.

The link between a firm’s export activity and EI adoption achieves higher dominance, once EI is restricted to its process-based components. Particularly, the correlation between highly internationalised firms and the breadth of EI adoption turns significant at the five-percent level in the full sample (column 3). Still, this relationship is especially conspicuous for Eastern European countries. In line with prior results, firms in Eastern European countries that generate the largest share of
turnover abroad, are more likely to adopt different process-based EIs at the one-percent level. Additionally, firms that report some exports are significantly more likely to report more EIs at the five-percent level.

The results for exposure to EPS and other dependent variables remain broadly comparable to our earlier results for the pooled regression. Table 6 includes the results for product-based EIs.

The results reveal that the correlation between exports and EI adoption is exclusively driven by process-based EIs. There is no significant effect in any specification, once EI is restricted to product-based EIs. Such a difference is not observable for exposure to foreign EPS stringent markets nor the remaining covariates. We next discuss the empirical results in line with our hypothesis and economic importance.
Table 6. Empirical results on product-based EI adoption and the breadth of product-based EI adoption.

| VAR.       | Logit Full sample | PPML Full sample | Logit East | PPML East |
|------------|-------------------|------------------|------------|----------|
| Exporter   | 0.011 (0.011)     | 0.002 (0.002)    | 0.026 (0.019) | 0.021 (0.044) |
| Exp. dom.  | −0.007 (0.012)    | −0.017 (0.031)   | 0.016 (0.015) | 0.020 (0.037) |
| Market EPS | 0.200*** (0.055)  | 0.527*** (0.147) | 0.148*** (0.056) | 0.317** (0.131) |
| Non-m. EPS | 0.144*** (0.071)  | 0.253 (0.204)    | 0.047 (0.067) | −0.054 (0.155) |
| MNC        | 0.003 (0.010)     | 0.009 (0.020)    | −0.002 (0.013) | −0.005 (0.024) |
| Ext. coop. | 0.036*** (0.005)  | 0.060*** (0.009) | 0.032*** (0.005) | 0.058*** (0.009) |
| R&D        | 0.057*** (0.008)  | 0.142*** (0.019) | 0.063*** (0.013) | 0.138*** (0.026) |
| Know-how   | 0.057*** (0.012)  | 0.136*** (0.023) | 0.086*** (0.013) | 0.164*** (0.028) |
| Subsidies  | 0.026*** (0.008)  | 0.038** (0.019)  | 0.043*** (0.012) | 0.087*** (0.028) |
| (In) turn. | 0.010*** (0.003)  | 0.032*** (0.004) | 0.018*** (0.003) | 0.049*** (0.006) |
| EPS (home) | 0.129*** (0.047)  | 0.275*** (0.064) | 0.155*** (0.017) | 0.307*** (0.014) |
| East       | −0.133*** (0.019) | −0.334*** (0.050) | −0.133*** (0.019) | −0.334*** (0.050) |

| Observations | 23,653 | 23,653 | 23,653 | 23,653 | 13,295 | 13,295 | 13,295 | 13,295 |
| Country     | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |
| Sector      | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |
| Year        | 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

4.3. Discussion of main results

Hypothesis 1 predicts that exposure to market-related mechanisms for higher environmental quality on foreign markets boosts the adoption of environmentally beneficial innovation. Our empirical results support this hypothesis. The positive correlation is observable for both measures of EI (any EI and the breadth of EI). Moreover, the pattern is reflected in both samples (full sample and Eastern European sample). Figure 3 illustrates the marginal effects for the adoption of environmentally beneficial innovations, basing the values on the marginal effects reported in Table 4 (columns 2, 4, 6 and 8).

Shifting from an EPS exposure of 0.4 to an EPS exposure of 1.6, increases the predicted likelihood for EI adoption from 42.9% to 69.8% – an increase of almost 17 percentage points. In Eastern European countries, the corresponding increase is 18.6 percentage points (43.4% to 62%). These changes are economically meaningful, in terms of magnitude. A similar increase is observable for the breadth of EI.
adoption. Here, the predicted magnitude increases by 1.84 EIs (1.45 to 3.29 EIs) in the full sample. For the Eastern European sample, the increase amounts to 1.04 EIs (1.53 to 2.57 EIs).

We take from this finding that firms are attuned to foreign stakeholders’ demands, adjusting their adoption of environmentally beneficial innovation, when exposed to higher EPS in importing markets. In line with Newman et al. (2018), foreign stakeholders differ in their demand for sustainable production. Looking back over our results collectively, our findings indicate that demand-pull (consumer demand) and regulation-push (environmental regulation) is not restricted to domestic stakeholders but also includes foreign stakeholders.

Such a clear-cut relationship is lacking for its sister variable, non-market EPS. When the latter increases, firms are more likely to adopt any EI. However, regarding the breadth of EI activity, there is no significant effect.

The second hypothesis predicts that exports induce firms to adopt process-based EI. This effect, we expect to be particularly pronounced in Europe’s catch-up economies. Figure 2 illustrates the predictive margins and significance intervals (95%), based on Table 5 (columns 1, 3, 5 and 6), splitting the results by the origin of the firm.

We begin by noting, that export activity positively correlates with the adoption of environmentally beneficial process innovations. A similar correlation is not observed for product innovations. Restricting the sample to Eastern Europe reveals that especially firms from European catch-up countries stand to benefit significantly from

**Figure 2.** Predictive margins of EI adoption depending on the exposure to foreign market-related EPS split by firms’ origin.
exports, a finding that might explain the difference between the cross-country study of Ghisetti, Marzucchi, and Montresor (2015) compared to the single-country studies of Cainelli, Mazzanti, and Montresor (2012), De Marchi and Grandinetti (2012), Chiarvesio, Marchi, and Maria (2015) and Peñasco, Del Río, and Romero-Jordán (2017). Switching to exporting makes a firm significantly more likely to adopt an environmentally beneficial process innovation (4.8 percentage points more likely). For the most intensive exporters, the effect rises to 5.4 percentage points. Given the relatively low adoption rates in Eastern European countries, these results are statistically and economically meaningful.

This difference in our results for the full and the Eastern European sample cautions against the usage of a one-size-fits-all estimation, when attempting to calibrate a policy of environmental convergence.

In addition, we find some preliminary evidence for an association between exports and the breadth of process-based EI. However, in the full sample, this correlation can only be seen for the adoption of environmental processes (five-percent level), for the most intensive exporters. In Eastern European countries, these highly internationalised firms are predicted to adopt 1.89 process-based EIs compared to a baseline of 1.6 for non-exporters, an increase of 18.1% and significant at the one-percent level. We refer from these results that the boost in EI adoption is economically meaningful, accelerating the catch-up progress for Eastern European firms.
Collectively, we interpret our findings for exports and the adoption of environmentally beneficial process innovations as a strong vindication of trade-related knowledge flows (Horbach 2016; Keshminder and Del Rio 2019) and the technique effect that underpins learning-by-exporting (Antweiler, Copeland, and Taylor 2001; De Loecker 2007). Interestingly, we do not find a significant correlation between product-based EIIs and exports. However, firms exposed to environmentally demanding foreign markets show higher product-based EI adoption rates, pointing to a possible trade-transmitted demand for clean products. The next section includes robustness checks to verify our key results.

4.4. Robustness

Multinational status is expected, almost by definition, to affect the export strategy of a firm. In concrete terms, horizontal FDI can be viewed as a substitute for exports. In this case, firms serving foreign markets can do so by transferring product to their affiliated plants. Alternatively, by applying vertical FDI, multinational firms can fragment their production across different countries (Antràs and Yeaple 2014). In order to eliminate this source of disturbance, which makes it difficult to draw any accurate predictions from our data, we exclude multinational firms from the sample. The results for this adjustment are reported in Table 7.

Our key results for Hypothesis 1 and Hypothesis 2 remain robust against an exclusion of multinational firms. In line with our main specification, EPS (market-related) remains highly significant in all specifications. Exports and the adoption of environmentally beneficial innovation are significantly correlated in the full sample (column 1). This correlation is also repeated in the restricted sample (column 5). In contrast to our main specification, the returns to exporting are slightly lower for the most internationalised firms. However, turning to the breadth of EI, we again witness how the environmental footprint of Eastern Europe’s most highly internationalised firms, stands to improve most from the activity of exporting. This finding underscores the importance of learning-by-exporting effects in accelerating the green transition within Europe’s catch-up economies. We now turn to the last section, including a discussion of our main results as well as deriving policy implications.

5. Conclusion

We investigate the connection between a firm’s exports and its decision to adopt and broaden its EI, applying firm-level data for two waves of the Community Innovation Survey (CIS) merged with information from the World Input-Output Database. Altogether, we cover 14 European countries, including nine Eastern European catch-up countries. Our aim is to examine how export activity relates to the environmental catch-up progress of Europe’s laggard economies. In addition, we investigate the role of foreign demand-pull and regulation-push by incorporating the OECD EPS index to denote the

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8The results are also robust for process-based EI and product-based EI, which we do not report here, but are available on request.
Table 7. Empirical results on EI adoption and the breadth of EI adoption excluding MNCs.

| VAR.     | (1) Logit | (2) Logit | (3) PPML | (4) PPML | (5) Logit | (6) Logit | (7) PPML | (8) PPML |
|----------|-----------|-----------|----------|----------|-----------|-----------|----------|----------|
| Exporter | 0.042***  | 0.046***  | 0.083    | 0.088    | 0.061***  | 0.055***  | 0.184*   | 0.120    |
| (0.012)  | (0.012)   | (0.063)   | (0.067)  | (0.017)  | (0.018)   | (0.100)   | (0.111)  |
| Exp. dom. | 0.035***  | 0.063***  | 0.142*   | 0.305**  | 0.052***  | 0.039***  | 0.291*** | 0.183*   |
| (0.011)  | (0.015)   | (0.076)   | (0.089)  | (0.015)  | (0.017)   | (0.091)   | (0.107)  |
| Market EPS | 0.223***  | 1.744***  | 0.192*** | 1.127*** | 0.227***  | 0.211***  |          |          |
| (0.075)  | (0.467)   | (0.064)   | (0.364)  |          |          |          |          |
| Non-m. EPS | 0.257***  | 0.092    | 0.170*   | 0.068    |          |          |          |          |
| (0.087)  | (0.622)   | (0.091)   | (0.462)  |          |          |          |          |
| Ext. coop. | 0.053***  | 0.062***  | 0.204*** | 0.233*** | 0.064***  | 0.066***  | 0.227*** | 0.211*** |
| (0.007)  | (0.007)   | (0.026)   | (0.025)  | (0.009)  | (0.010)   | (0.030)   | (0.027)  |
| R&D       | 0.055***  | 0.083***  | 0.380*** | 0.499*** | 0.064***  | 0.110***  | 0.345*** | 0.468*** |
| (0.011)  | (0.013)   | (0.050)   | (0.058)  | (0.018)  | (0.018)   | (0.081)   | (0.084)  |
| Know-how  | 0.043***  | 0.042***  | 0.360*** | 0.373*** | 0.089***  | 0.075***  | 0.463*** | 0.403*** |
| (0.017)  | (0.015)   | (0.056)   | (0.056)  | (0.017)  | (0.017)   | (0.093)   | (0.085)  |
| Subsidies | 0.048***  | 0.025**   | 0.181*** | 0.055    | 0.072***  | 0.075***  | 0.303*** | 0.286*** |
| (0.008)  | (0.011)   | (0.047)   | (0.057)  | (0.012)  | (0.013)   | (0.077)   | (0.073)  |
| (In) turn. | 0.011**   | 0.014***  | 0.108*** | 0.117**  | 0.020***  | 0.034***  | 0.144*** | 0.197*** |
| (0.005)  | (0.005)   | (0.022)   | (0.021)  | (0.003)  | (0.004)   | (0.014)   | (0.021)  |
| EPS (home) | 0.118***  | 0.423***  | 0.921*** | 2.823**  | 0.117***  | 0.401***  | 0.735*** | 2.586*** |
| (0.039)  | (0.069)   | (0.283)   | (0.568)  | (0.041)  | (0.059)   | (0.269)   | (0.390)  |

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

demand for environmental quality. Overall, our data allow us to shed light on the role of trade in promoting EI, and ultimately in helping countries to transition towards a green economy.

Contrary to Cainelli, Mazzanti, and Montresor (2012), De Marchi and Grandinetti (2012), Chiarvesio, Marchi, and Maria (2015) and Penasco, Del Rio, and Romero-Jordán (2017), who all use single-country data, we find a positive correlation between a firm’s EI adoption and export activity. This is in line with Ghisetti, Marzucchi, and Montresor (2015) who exploit the multi-country CIS and report a positive correlation. We go beyond Ghisetti, Marzucchi, and Montresor (2015) and explore whether the more homogeneous Eastern European countries, part of the sample, drive the results and find that export activity of firms in Europe’s catch-up economies associates with higher EI adoption propensities and a higher breadth of EI. Notably, we find that the relation is limited to adoptions of environmental beneficial process innovations and is not reflected for product-based EI. We take these results as indicative of learning-by-exporting, an important mechanism allowing laggard countries to catch-up with their more advanced

peers. Analogously, this restriction of our findings to process-based EIs is suggestive of a firm technique effect, the reduction of a firm’s environmental footprint through the generation of efficiencies.

Turning to the destination of exports, we find that firms produce in a more environmentally efficient way when faced with increased exposure to environmentally stringent markets. This effect is most conspicuous when firms are exposed to market-related EPS. Reassuringly, our results are observable for both the full- as well as the Eastern European samples and to various definitions of the outcome variable (EI adoption and EI breadth). We can conclude that foreign regulation-push and demand-pull help to reinforce positive environmental outcomes. The latter finding contributes to our understanding on how foreign stakeholders’ demand for sustainable production relates a firm’s production decision, i.e. previously investigated by Newman et al. (2018) in the context Corporate Social Responsibility.

Accordingly, and independent from a country’s stage of development, firms respond to foreign stakeholder preferences, incorporating these preferences into their decision to broaden EI. The revealed relation between firms’ export activity, exposure to stakeholders’ environmental demand and EI adoption links to a hidden environmental benefit of the Eastern enlargement of the European Union over the previous decades. However, we reveal – at least descriptively – that EI adoption rates are still significantly lower in Europe’s catch-up economies. Accordingly, Eastern European firms should still step-up to the mark to reach Europe’s green targets, i.e. embodied in the European Green Deal. The diffusion of clean technologies represents a basic pillar of the European Green Deal. Assisting Eastern European firms to serve the European single market might represent a tool for decision takers to promote convergence in environmental standards. Generally, targeting support at the exporting sector, particularly firms exporting products to environmentally stringent countries, should translate into positive environmental effects. Accordingly, firms should be helped to align their products and processes to the demands of stakeholders in the most environmentally regulated countries, also those countries beyond the European Union.

The view of globalisation and trade has been recently (and justifiably) subject to a certain amount of scrutiny. However, this debate is more nuanced than at first appearances. It is important that policy makers do not lose sight of some of the more positive aspects of trade, including its ability to trigger a convergence in environmental standards.

As is usual in any analysis of this kind, we should comment on the limitations of our study. A data panel, including a firm-identifier, might have allowed us to empirically explore – in even greater depth – the relation between export activity and a firm’s EI adoption decision. Also, access to a firm’s exact location might have helped to shed light on the role of geographic location, e.g. to test if EI adopters tend to cluster in specific regions that are linked to highly demanding international markets. Arguably, the impact of foreign customers (market demand) and foreign regulation is, in some way, synonymous. This is because consumer preferences get enshrined into regulation via the voting system (Antweiler, Copeland, and Taylor 2001). Nevertheless, separating these two mechanisms remains a goal for future work. We should also note that our analysis does manage to capture some of the progress in Europe’s environmental catch-up. However, our full sample is not representative of the entire European Union. In particular, our coverage of
Western European countries is relatively incomplete. All in all, we should emphasise that the countries covered by our data are relatively wealthy, at least on a global scale. Future research might consider extending the sample to include developing countries.

In terms of accelerating the European green transition, our main message is that the green transition and trade are not mutually exclusive. Exporters from catch-up economies appear to benefit from learning-by-exporting and trade-induced technique effect.

Acknowledgments

We would like to thank Richard Franke, Holger Görg, Jens Horbach, Beata Javorcik, Thilo Kroeger, Jakob Lehr, David Maddison, Giovanni Marin, Massimiliano Mazzanti, Horst Raff, Christina Raasch, Katrin Rehdanz, Claas Schneiderheinze, Frauke Steglich, Ruijie Tian, Julian Vehrke, other researchers of the KCG and the highly helpful comments by two anonymous referees. Additionally, we thank seminar/conference/workshop participants at the Trinity Business School Seminar Series 2021, the Annual Conference of the Verein für Socialpolitik 2019, the EEARE 2019, the DRUID 2019, Annual CERCIS Workshop 2019 in Ferrara, the INFER Workshop in Coimbra 2019, the Götinger Workshop in International Economics 2019, the Kiel Centre for Globalization Workshop 2018, the Kiel Institute Young Researchers Seminar 2018 and the Aarhus-Kiel Workshop 2017. Moreover, we acknowledge financial support from the Leibniz Association through the Leibniz Science Campus KCG (Grant number is SAS-2016-IfW-LWC).

Data availability statement

We employed the Community Innovation Survey (CIS) 2008 and 2014. The microdata is restricted in access and usage, but is free of charge. Key steps are to apply the research organisation to be recognised 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. Moreover, we acknowledge the kind support when contacting the Eurostat help-desk.f

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Leibniz-Gemeinschaft [SAS-2016-IfW-LWC].

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More information about the CIS is available at https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey.
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## Appendix

Table A1. Summary statistics.

| VARIABLES                           | (1) N  | (2) mean | (3) sd  | (4) min | (5) max |
|-------------------------------------|--------|----------|---------|---------|---------|
| EI adoption                         | 23,653 | 0.609    | 0.488   | 0       | 1       |
| Nr. of EI adoption                  | 23,653 | 2.518    | 2.680   | 0       | 8       |
| Process-based EI adoption           | 23,653 | 0.584    | 0.493   | 0       | 1       |
| Nr. of process-based EI adoption    | 23,653 | 1.736    | 1.816   | 0       | 5       |
| Process-based EI adoption           | 23,653 | 0.403    | 0.491   | 0       | 1       |
| Nr. of process-based EI adoption    | 23,653 | 0.782    | 1.087   | 0       | 3       |
| Some exports                        | 23,653 | 0.432    | 0.495   | 0       | 1       |
| Exports dominate                    | 23,653 | 0.317    | 0.465   | 0       | 1       |
| Market EPS                          | 23,653 | 1.186    | 0.192   | 0.486   | 1.589   |
| Non-market EPS                      | 23,653 | 1.340    | 0.118   | 0.812   | 1.814   |
| MNC                                 | 23,653 | 0.175    | 0.380   | 0       | 1       |
| Ext. coop. breadth                  | 23,653 | 0.871    | 1.608   | 0       | 7       |
| R&D                                 | 23,653 | 0.464    | 0.499   | 0       | 1       |
| Know-how acquisition                | 23,653 | 0.198    | 0.399   | 0       | 1       |
| Subsidies                           | 23,653 | 0.284    | 0.451   | 0       | 1       |
| (ln) turnover                       | 23,653 | 15.44    | 2.031   | 7.085   | 24.46   |
| Domestic EPS                        | 23,653 | 0.564    | 0.192   | 0       | 1       |