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The impact of foreign direct investment in emissions reduction targets: evidence from high- and middle-income countries

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Resumo

A consciência ambiental tornou-se um tópico de investigação como consequência do aquecimento global. Durante vários anos, os países têm enfrentado um *trade-off* entre o crescimento económico e os objetivos de redução das emissões de dióxido de carbono. A globalização tem uma elevada relevância na definição do desempenho ambiental dos países. Um dos processos incluídos na globalização é o fluxo de investimento estrangeiro. Alguns países lutam para equilibrar a sua necessidade de entradas de investimento estrangeiro – que chegam, de modo geral, devido às suas leis ambientais mais relaxadas – com a necessidade de melhorar a sua qualidade ambiental. O modelo *Panel Autoregressive Distributed lag* foi aplicado para avaliar os impactos que o investimento direto estrangeiro tem as emissões de dióxido de carbono de 21 países divididos por nível de rendimento, entre 2001 e 2017. O nível de eficiência, inovação e regulação dos países recetores foram considerados, de maneira a compreender melhor a complexidade do fenómeno do investimento direto estrangeiro. As medidas regulatórias dos países de alto rendimento demonstram não auxiliar na redução das emissões no curto prazo, algo que merece um debate pormenorizado. O investimento direto estrangeiro diminui as emissões nos países de elevado rendimento, enquanto aumenta nos países de médio rendimento. Contudo, a capacidade absortiva dos países é crucial para fazer com que estes países beneficiem no longo-prazo, tal como os países de alto rendimento beneficiam. A abertura comercial é altamente influenciada pela regulação ambiental nos países de médio rendimento. A *Pollution Haven Hypothesis* é sustentada, o que significa que as indústrias poluidoras estão a ser transferidas dos países mais desenvolvidos para outras regiões do mundo, impactando o ambiente onde elas se alocam.

Palavras-chave

Investimento direto estrangeiro; Emissões de dióxido de carbono; *Pollution Haven Hypothesis*; regulação; eficiência energética

Resumo alargado

A globalização tem um grande impacto no desenvolvimento dos países, assim como o fenómeno associado de investimento direto estrangeiro (FDI) que é considerado uma grande fonte de crescimento económico dos países recetores (e.g. Balsalobre-Lorente et al., 2019). No entanto, é necessário compreender de que modo este FDI pode comprometer o desenvolvimento sustentável dos países. A *Pollution Halo Hypothesis* sustenta o aspeto mais positivo do FDI. Para além de ser um impulsionador de crescimento económico, os países beneficiam da transferência de novas maquinarias e da difusão de conhecimentos, por exemplo. Numa tentativa de atrair mais FDI, os países menos desenvolvidos criam condições favoráveis para esses investimentos, entre elas o relaxamento das regulações ambientais. Estes países atraem FDI através da vantagem comparativa em indústrias poluidoras. Aqui começam os pontos negativos. As empresas filiadas em países com mais restrições ambientais transferem as suas indústrias poluidoras para países com leis mais relaxadas, de modo a evitar o aumento dos seus custos. Esta transferência é conhecida na literatura como *Pollution Haven Hypothesis*.

Deste modo, torna-se imprescindível entender de que modo o FDI afeta o ambiente, para que os decisores políticos consigam, caso necessário, reajustar as suas políticas e atingir as metas de desenvolvimento sustentável. Esta investigação pretende responder a questões tais como: (i) qual o impacto do FDI no ambiente nos países recetores?; e (ii) estarão os países de alto rendimento a transferir as suas indústrias poluidoras para países com leis ambientais mais relaxadas? O modelo *Autoregressive Distributed Lag* (ARDL) foi utilizado, para 21 países divididos por nível de rendimento, com um horizonte temporal entre 2001 e 2017. Como referido por Hao et al., (2020), as decisões de saída do FDI dependem das necessidades dos países emissores: matérias-primas ou recursos naturais, mercado, e tecnologias, por exemplo. Isto também demonstra que os impactos que o FDI tem depende das características dos países recetores. Por isso, a consideração dos níveis de regulação ambiental, eficiência e inovação dos países preenche uma lacuna na literatura. Por exemplo, países com níveis de regulação ambiental elevados não serão atrativos para indústrias poluidoras, do mesmo modo que países com níveis baixos de eficiência e inovação serão pouco atrativos para indústrias altamente automatizadas, pois irão aumentar os custos de ajustamento (Adom et al., 2019). A análise do efeito do FDI nas emissões de CO_2 globais e nas emissões do sector industrial produzem linhas orientadoras úteis e diretas nesta temática, e pode ser considerada uma análise de robustez.

A variável CO_2 foi utilizada como *proxy* da poluição e a variável CO_2 do sector industrial representa a poluição provocada por esse sector, foram ambas utilizadas como variáveis dependentes. Outras variáveis são: stock interno de investimento direto estrangeiro, a formação bruta de capital fixo, o comércio, as patentes e os ganhos relacionados aos impostos ambientais. A eficiência energética dos países foi também considerada e foi calculada através do rácio da produção industrial sobre o consumo de energia. As fontes dos dados são o *World Development Indicators* do *World Bank, International Energy Agency* e a *Organisation for economic co-operation and development statistics*. Foram realizados testes de raízes unitárias de primeira e segunda geração para verificar a ordem de integração das variáveis. A existência de heterocedasticidade, dependência seccional e autocorrelação de primeira ordem, foi testada e a sua existência foi controlada através da utilização do estimador Driscoll & Kraay (1998), uma vez que produz resultados mais robustos na presença destas características.

A formação bruta de capital fixo e a abertura comercial aumentam a poluição, no curto e no longo-prazo. No entanto, a abertura comercial não se demonstra significante no longo-prazo nos países de médio rendimento. A eficiência contribui para a redução das emissões de CO_2 principalmente no sector industrial. As patentes não demonstram ser estatisticamente significantes nos países de alto rendimento, e aumentam as emissões nos países de médio rendimento. A regulação ambiental aumenta a poluição no curto prazo nos países de alto rendimento, o que é inesperado. Nos países de médio rendimento, a regulação diminui as emissões no longo prazo. Os resultados do sector industrial suportam a maioria dos resultados das emissões gerais. No entanto, as patentes e a regulação não demonstram ser estatisticamente significantes para as emissões neste sector. Isto significa que os decisores políticos não estão a prestar especial atenção à inovação e regulação do setor industrial. A *Pollution Haven Hypothesis* é suportada para os países de médio rendimento, mas apenas no curto prazo. No longo prazo, o FDI diminui a poluição geral, o que realça a importância da capacidade absortiva de tecnologia destes países. O FDI diminui as emissões de CO_2 nos países de alto rendimento, o que suporta a *Pollution Halo Hypothesis*.

Sabendo que o cenário ideal de leis ambientais semelhantes em todo o mundo e a inexistência de corrupção é utópico, a definição de uma estrutura legal estável, a cooperação entre os decisores políticos dos países e a combinação de diferentes instrumentos políticos (impostos e subsídios) poderão atenuar os efeitos negativos do FDI no ambiente e mesmo extingui-los: os países de alto rendimento não vão transferir as suas indústrias poluidoras, uma vez que os riscos não serão compensatórios, e os países de médio rendimento não vão aceitar a entrada de FDI poluidor, uma vez que vai degradar o seu ambiente, trazendo complicações com os acordos internacionais existentes (e que devem continuar presentes em todo o mundo).

Abstract

Environmental awareness has become a research topic worldwide as a consequence of global warming. For several years, countries have been facing a trade-off between economic growth and targets to reduce carbon dioxide emissions. Globalization has high relevance in defining the environmental performance of countries. One of the processes within globalization is the flow of foreign investments. Some countries struggle to balance the need for inward foreign investments – arriving on the whole due to their laxer environmental policies – with the necessity to improve the quality of their environment. With this impasse in mind, a Panel Autoregressive Distributed Lag was applied to evaluate the impacts of foreign direct investment on the carbon dioxide emissions of 21 countries divided into income levels, for a period ranging from 2001 to 2017. The efficiency, innovation, and regulation characteristics of the host countries are considered to better understand the complexity of the foreign direct investment phenomenon. Regulatory measures appear ineffective in reducing emissions in the short-run in high-income countries, something which deserves a lively debate. Foreign direct investment decreases emissions in high-income countries, while it increases in the short-run in middle-income countries. Notwithstanding, the technology absorptive capacity of middle-income countries is prominent to make them benefit in the long-run, as high-income countries do. Furthermore, trade openness is highly influenced by environmental regulation in middle-income countries. The Pollution Haven Hypothesis is supported, meaning that polluting industries are being transferred from more developed countries to other regions of the world, impacting the environment where they are set up.

Keywords

Foreign direct investment; Carbon dioxide emissions; Pollution Haven Hypothesis; Regulation; Energy-efficiency

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Acronyms List

ARDL	Autoregressive Distributed lag
CD	Cross-Section Dependence
CIPS	Cross-Sectionally Augmented IPS
CO_2	Carbon Dioxide
ECM	Error Correction Model
EF	Energy Efficiency Index
FDI	Foreign Direct Investment
IEA	International Energy Agency
IPI	Industrial Production Index
GHG	Greenhouse Gas
MENA	Middle East and North Africa
PHH	Pollution Haven Hypothesis
RES	Renewable Energy Sources
R&D	Research and Development
UNCTAD	United Nations Conference of Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VIF	Variance Inflation Factor
WB	World Bank

1. Introduction

Environmental awareness diverges between countries, something which is reflected in their economic priorities. Countries have different reactions when faced with the trade-off between economic growth and carbon dioxide (CO_2) emissions reduction. Indeed, all countries want to increase their income, but environmental issues should not be disconnected from this goal. Foreign direct investment (FDI) could bring countries either benefits or drawbacks. Firstly, FDI is known as a source of economic growth (Balsalobre-Lorente et al., 2019). For that, countries are searching for FDI as an economic booster, mainly the countries with lower levels of development. On the one hand, these countries could enlarge their income and at the same time, benefit through the sharing of knowledge (Shahbaz et al., 2015) and green technologies (Mielnik & Goldemberg, 2002). On the other hand, their FDI could harm the environment through the transference of polluting industries (e.g, Baek, 2016).

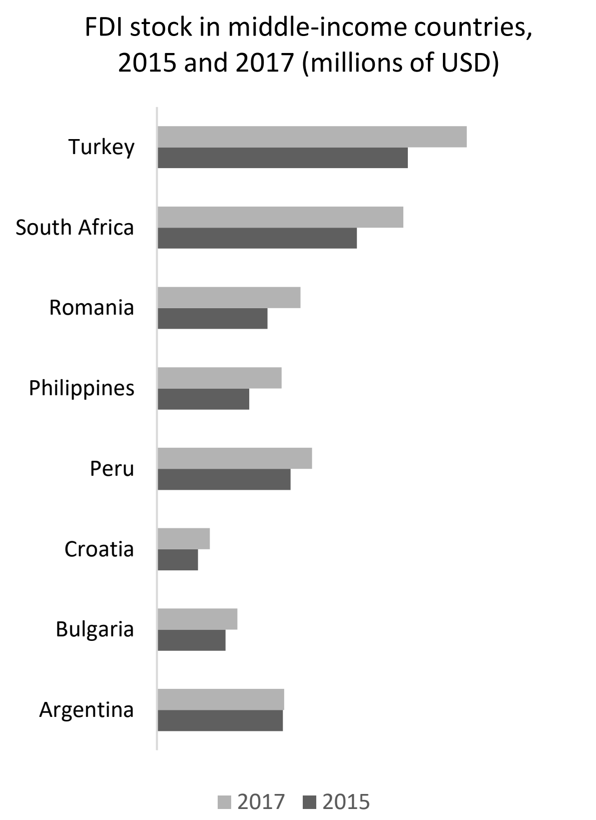
This is the primary concern regarding the relationship between FDI and the environment, and as such, countries could be facing a trade-off between FDI and emissions reduction. As stated in the World Investment Report, published by the United Nations Conference of Trade and Development (UNCTAD), in 2018, some countries are introducing policy measures that affect foreign investments, moving in the direction of liberalization, promotion, and facilitation of foreign investments (UNCTAD, 2019). This facilitation attracts more FDI, however, it will attract both clean and dirty FDI, and therein lies the problem. In such a way, it is crucial to know the effect of FDI on the environment to understand how policymakers can act to look for sustainable development targets.

Furthermore, it is of high relevance to fully understand the influence of income level on the transference of polluting industries among countries. Countries with higher environmental stringency could be transferring their polluting industries to countries with milder environmental laws to avoid higher environmental compliance costs, once environmental regulations raise the cost of key inputs to goods with pollution-intensive production. It is also important to discern if environmental regulations are producing the expected result of decreased pollution. Briefly, the central questions of this paper are: (i) What is the impact of FDI on the environment of host countries?; and (ii) Are high-income countries moving their pollution-intensive industries to countries with laxer environmental regulations?

To answer these central questions, the Autoregressive Distributed lag (ARDL) model was used focusing on 21 countries divided into income levels. The consideration of environmental regulation, efficiency, and innovation levels of the countries will help in interpreting the complexity of the FDI phenomenon. Furthermore, this approach divides the impacts into the short- and long-run, which jointly with the disaggregation of countries into income levels, and the scrutiny of the effect in the industry sector produces directed and useful guidance in this theme. This study analyses countries with different income levels since it provides better empirical evidence both to the analysis that jointly explores the Pollution Halo and Pollution Haven hypotheses, which is scarce in the literature about this theme (Balsalobre-Lorente et al., 2019).

Figure 1. FDI stock in high-income countries

Figure 2. FDI stock in middle-income countries



Graph source: own elaboration; **Data:** UNCTAD- FDI inward stock in millions of USD

One observes through Figures 1 and 2 that all countries chosen to be under scrutiny in this investigation increased their levels of FDI stock between 2015 and 2017. The Netherlands and the United Kingdom are highlight host countries among high-income countries with higher levels of FDI inflows as presented in Figure 1. The Netherlands has an attractive standard corporate income tax rate of 25%, with predictions to reduce to 21.7% in 2020 regarding the 2019 PWC worldwide tax summaries[1], with a lower rate of 19% to taxable profits up to 200.000€, that will further decrease to 16.5% in 2020. Furthermore, double taxation can be usually avoided in the Netherlands. All of this reflects the great treatment for foreign companies; these are the main reasons for the Netherlands to be highly attractive. The United Kingdom has a normal rate of corporation tax about 19% in 2019,

[1] https://taxsummaries.pwc.com/netherlands/corporate/taxes-on-corporate-income, 9 June 2020

which is also very attractive to foreign companies. But the main reason for the United Kingdom to be one of the principal recipient countries to FDI could be its high level of development, income, and economic performance also the population density which is highly relevant to the development of new companies. An interesting and current point related to this positive trajectory of FDI growth is that it could be affected by the Brexit, once trade (this is, exports and imports) to the European Union will potentially bring additional tariffs.

Regarding Figure 2, Turkey and South Africa are the countries with a major level of inward FDI stock among the countries under scrutiny. Recently, Turkey had implemented legislative reforms to facilitate foreign investments such as the Investment Support and Promotion Agency of Turkey (ISPAT), according to Santander Trade Markets[2]. Another example of the attractiveness of Turkey is their lower labor costs that could attract more FDI once they are positively linked as stated by Esiyok (2011). However, Turkey loses attractivity by the slow pace of privatisation process, the high inflation levels, and corruption (Loewendahl & Ertugal-Loewendahl, 2001). According to Santander Trade Markets[3], South Africa has strong points to attract foreign investments, as an abundance of natural resources, the great potential on tourism and retail sectors, and a strong mining sector which represents the main relevance of this economy. In turn, it also has some less attractive points, as economic instability due to corruption, lower access to electricity, and the import-export processes that may be difficult. Both Turkey and South Africa are extremely dependent on FDI inflows, which make these countries change their policies to attract as much FDI as possible.

Turkey has been trying to integrate the European Union, which reflects the economic stability of this country lately, reflected in European regulations and trade standards. The geographic location of Turkey is very attractive once it is near Europe, Asia, and the Middle East and North Africa (MENA) economic zone, which is favorable to trade. The same for South Africa that has a geographical locational that ensures access to the Sub-Saharan markets. One states that it is good to boost the economic performance of both Turkey and South Africa; however, the consequences go further the positive effect on economic performance and could affect the environment. According to the Presidency of the Republic of Turkey Investment Office[4], 24,1% of the cumulative FDI during the 2003-2018 period is in the manufacturing sector. Moreover, in South Africa, the mining sector corresponds to 21,2% of FDI inflows, and manufacturing with 15,9%, as maintained by Santander Trade Markets in South Africa. The mining belongs to the primary sector of the industry, which

[2] https://santandertrade.com/en/portal/establish-overseas/turkey/foreign-investment, 9 June 2020
[3] https://santandertrade.com/en/portal/establish-overseas/south-africa/foreign-investment, 9 June 2020
[4] https://www.invest.gov.tr/en/whyturkey/pages/fdi-in-turkey.aspx, 9 June 2020

means that it is extremely pollutant, and an increase in their production level hugely impacts the environment worldwide. Moreover, manufacturing, although be in the secondary sector of the industry is also highly pollutant, considering that is the process of transforming raw materials into goods.

Briefly, the majority of middle-income countries under analysis have greater participation of FDI inflows to the mining and manufacturing sectors. Even if these countries must attract FDI, it is highly required to implement stringent criteria of FDI inflows mainly related to environmental protection, which encourage FDI to transfer new and eco-friendly technologies, that can help these countries in controlling pollution. Notwithstanding, some high-income countries also have a wide percentage of FDI inflows to these sectors. For example, in 2017, Spain has 31,8% of FDI inflows to the manufacturing sector, and Norway has 27% of FDI inflows to the mining sector and 14,1% to the manufacturing sector. This upsurges some questions. For example, considering countries that receive FDI directed to the manufacturing sector, have FDI inflows the same impacts in high- and middle-income countries? Or high-income countries are taking advantage of middle-income countries to transfer these polluting industries? In fact, even if the FDI inflow occurs in the same sector of the industry, each country has different levels of efficiency, innovation, eco-friendly technologies, and environmental regulations, which will make countries deal differently with the same industries, mostly due to the different environmental standards and regulations. These questions will also be further investigated in this paper.

This paper fills a gap in the literature as it considers the innovation, regulation, and efficiency levels of the host countries in the relationship between FDI and emissions. It not only debates the impact of these variables on pollution but further assesses complementary information about the capacity that these variables have to change impacts between each other. A country that wants to transfer green technologies and knowledge through FDI will evaluate some capabilities of the recipient countries, such as their innovation, and efficiency skills. Adversely, a country that wants to relocate its polluting industries to another country to avoid environmental taxes, will search for a country with lower environmental regulations. This paper contributes to the enlargement of knowledge in this area, accompanied by empirical evidence that reveals that applied regulatory measures seem not to be efficient in helping to reduce emissions in high-income countries.

This paper exposes that the regulatory structure of these countries must be discussed, as is in this paper, and that it should be further investigated. Trade openness is highly influenced by regulation in middle-income countries. These countries seem to be focused only on developing new patents with the aim of increasing their income. The dichotomous impacts found between the short- and long-run, further emphasizes the use of the ARDL model; otherwise, if that separate analysis was not carried out, misleading results could be achieved. Indeed, FDI is shown to decrease overall pollution and from the industry sector in high-income countries, while increases it in middle-income countries in the short-run. This seems to support the transference of polluting industries from high-income countries to middle-income countries, that is, supporting the Pollution Haven Hypothesis (PHH). However, middle-income countries could be receiving clean FDI as well, but as will be discussed in this paper, their technology-absorptive-capacity influences the impact of FDI on the environment. The ARDL model also provides better evidence of the technology-absorptive-capacity of the countries as it analyses the impacts through time.

The rest of the paper is organized as follows: Section 2 presents a theoretical background; Section 3 discloses the data and methodology; Section 4 reveals the results and discussion about overall CO_2 emissions and those from industry, with a brief comparison between models; and Section 5 concludes.

2. Literature Review

The industrial structure of countries has been changing since the industrial revolution. As industrial output has increased, so have CO2 emissions, and with that, environmental degradation has emerged. FDI has an important role in economic growth (Omri et al., 2014). However, besides the effect on economic growth, FDI also impacts the environment of host countries. The relationship between FDI and the environment was initially analysed through the impact of international trade, and posteriorly considering the effect of FDI on the environmental quality of host countries (Shahbaz et al., 2015). International trade (reflected in trade openness) is still of great value and its effect is commonly evaluated in this theme (e.g., Essandoh et al., 2020; Sbia et al., 2014). Besides the high correlation and Granger causality with FDI, trade openness has an effect on pollution. Essandoh et al., (2020) find that trade openness is environmental favourable for developed countries, with no evidence of impact in developing countries. However, as noted by Ren et al., (2014), trade openness could harm the environment if countries have a comparative advantage in dirty production under weak environmental regulations. The unwise behaviour of some countries that need to increase their income impacts the whole environment, increasing pollution, and ultimately leading to climate change. However, unlike the recessions faced by world economies, climate changes may be irreversible (Doytch & Uctum, 2016).

The characteristics of the countries matter when to evaluating the impact of FDI on the environment, because FDI, *per se*, does not have an impact as stated by Pazienza (2019). There is diverse empirical evidence in the literature about the effect of FDI on the environment. For some countries, FDI reveals a positive and relevant role in reducing emissions due to the transference and adoption of greener technology. This technology boosts efficiency gains (Pao & Tsai, 2011) and improves environmental quality. However, in other countries, FDI increases CO_2 emissions (Ren et al., 2014) contributing to environmental degradation. Beyond the different characteristics of the countries, also the adoption of different empirical methodologies or different periods could impact the conclusions made (Zhang & Zhou, 2016), as it is possible to conclude regarding Table 1.

In several reports, the effect of FDI on the environment has been divided into three categories: technique, structural, and scale effects (see Liang, 2009; He, 2008; Cole & Elliott, 2003). The technique effect is based on the diffusion of new and more efficient machines, for example, though FDI (Pazienza, 2019), which decreases the emissions per unit of a good produced. This effect also supports that the introduction of environmental regulations can improve the environment decreasing emissions (Shahbaz et al., 2018). The structural effect is related to the characteristics of an economy. For instance, an economy that produces energy-intensive goods consumes more energy than an economy specialized in the services sector (Pazienza, 2019). Succinctly, the effect of FDI depends on the comparative advantage and the specialization sectors of that economy (Shahbaz et al., 2018). Lastly, the scale effect states that FDI increases the industrial output in the host country, then increasing energy consumption and CO_2 emissions (Pao & Tsai, 2011). As stated by Hao et al., (2020), the FDI outflow decisions could be divided into three types: resources-seeking, market-seeking, and technology-seeking. Countries that are resources-seeking, will invest in countries with an abundance of resources, while market-seeking countries will search and invest in a country with market potential. Moreover, technology-seeking FDI will invest in a country with higher levels of technology and knowledge and will further participate in the management activities of this country, to gain "know-how", for example. This type of FDI will benefit the domestic environment, increasing the human capital level of the host countries, and raising the competitiveness of the source firm (Pradhan & Signh, 2008).

As such, the countries' characteristics could amplify the impacts of FDI. It can harm the environment in countries with lower environmental consciousness (Xing & Kolstad, 2002), meanwhile, it can improve the environmental quality in countries with higher environmental awareness (Demena & Afesorgbor, 2019). These characteristics are more exploited in the three main hypotheses associated with the FDI-environment nexus: Porter, Pollution Halo, and Pollution Haven hypotheses. The Porter hypothesis states that FDI can improve the environmental quality of the host countries due to the introduction of new technologies that consume less energy; the so-called eco-friendly technologies (C. Zhang & Zhou, 2016; Mielnik & Goldemberg, 2002). The main reason for this is the environmental regulations that encourage firms to invest in green innovation (C. Shen et al., 2020) to improve their efficiency. However, both regulation and the development of new technologies leads to an increase in costs. This reveals that it is important to bear in mind the cost-benefit analysis because regulations can only promote innovation when the benefits exceed the costs. In other words, regulation should offset the environmental compliance costs to benefit the environment and improve the firms' competitiveness (C. Shen et al., 2020).

The Pollution Halo Hypothesis is built on the positive effect that FDI has on the environment. The transfer of new technologies that can decrease energy consumption (Mielnik & Goldemberg, 2002), and the transfer of business knowledge- so-called "know-how"- (Shahbaz et al., 2015) are some examples of benefits that FDI can bring to countries if multinationals are less pollution-intensive (Cole et al., 2011). The countries' characteristics have relevance to defining this impact because countries with higher levels of environmental consciousness would not allow the entry of polluting FDI. Finally, the PHH states that FDI harms the environment in host countries (e.g., Baek, 2016; Al-mulali, 2012). Countries with strict environmental regulations transfer their polluting industries to countries with more relaxed environmental laws, to run away from further additional environmental costs and taxes (Shahbaz et al., 2015). However, PHH only occurs when the industries transference is relatively easy and does not involve high costs, which divides industries into two groups as Dou & Han, (2019) states: strongly, and weakly mobile pollution industries. Strongly mobile industries will be relocated when an increase in the stringency of the environmental regulations happens, and weakly mobile industries will invest in R&D to gain efficiency, obtaining an "Innovation Compensation" effect (Dou & Han, 2019).

As such, environmental regulation is the main focus of two previous hypotheses which state that the effect of FDI on pollution depends on the environmental regulation level of host countries. Some literature linked the environmental regulation and the environmental performance of the countries, mainly reflected in the pollution level. On the one hand, environmental regulation could improve environmental quality, once increase the productivity and efficiency of the firms in that country mainly due to energy savings (N. Zhang & Choi, 2013), which means that regulation can decrease pollution (Hashmi & Alam, 2019). On the other hand, environmental regulation could produce an inhibitory effect on green innovation for some firms and industries, by imposing additional costs (Gray & Shadbegian, 2003). This negative effect could make industries to be transferred to countries with lower environmental standards (Z. Dong et al., 2020), as stated in PHH.

Energy-efficiency, and innovation upsurges in the debate about the effects of environmental regulation on pollution. The large literature about energy consumption states that it is detrimental to the environment, which means that advances in energy-efficiency could be helpful to reduce pollution (Balsalobre-Lorente et al., 2019). Both inflows of clean FDI and investment in R&D with the aim of innovation could provide energy-efficiency gains. As such, energy innovation policies are required, since economic growth cannot improve pollution by itself, and the continued promotion of energy innovation can reduce emissions (Balsalobre-Lorente et al., 2017). Furthermore, innovation can help countries to improve their environmental performance, reducing environmental compliance costs, but also could help countries to boost their sustainable economic growth (Balsalobre-Lorente et al., 2019).

Table 1. Literature review framework

Author(s)	Period	Study area	Method	Conclusions
Pao & Tsai (2011)	1980-2007 and 1992-2007 (Russia)	BRIC (Brazil, Russian Federation, India, and China)	Panel cointegration technique; Multivariate Granger causality	Strong bidirectional causality between emissions and FDI.
Omri et al., (2014)	1990-2011	3 regional sub-panels: Europe and Central Asia, Latin America and the Caribbean; the Middle East and North Africa; and sub-Saharan Africa.	Dynamic simultaneous-equation model	Bidirectional causality between FDI inflows and CO_2 emissions in all panels excluding Europe and North Asia.
Ren et al., (2014)	2000-2010	China's industrial sectors	IOA; Two-step GMM	FDI inflows deteriorate China's CO_2 emissions.
Sbia et al., (2014)	1975Q1-2011Q4	United Arab Emirates (UAE)	ARDL bounds testing approach; VECM Granger causality	FDI saves energy consumption; FDI Granger causes green energy.
Seker et al., (2015)	1974-2010	Turkey	ARDL; VECM based Granger causality	FDI Granger causes CO_2 emissions in the long-run; FDI increases pollution but with a small impact.
Shahbaz et al., (2015)	1975-2012	99 economies worldwide (high-, middle-, and low-income)	FMOLS	Inverted-U shaped relationship between FDI and CO_2 emissions in the global and middle-income panels; FDI reduces CO_2 emissions in high-income countries; FDI increases environmental degradation, confirming PHH, in low-income countries.
Zhu et al., (2016)	1981-2011	Association of South East Asian Nations (ASEAN-5): Indonesia, Malaysia, the Philippines, Singapore, and Thailand	Panel quantile regression	FDI decreases CO_2 emissions in the middle- and high-emissions countries, supporting the pollution halo hypothesis.
Sapkota & Bastola (2017)	1980-2010	14 Latin American countries (high and low-income countries)	Panel fixed and random effects models	FDI increases CO_2 emissions, which validates PHH, for both high- and low-income countries.
Shahbaz et al., (2018)	1955-2016	France	Bootstrapping ARDL bounds test	FDI degrades the environment
Rafindadi et al., (2018)	1990-2014	GCC (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates)	Panel ARDL estimation: PM); MG; and Dynamic fixed effects	While FDI inflows reduce environmental degradation, the energy consumption associated with the FDI inflows can lead to pollution, whereas energy consumption increases it.
Adom et al., (2019)	2000-2014	27 African countries	GMM	Concave effect of FDI on energy consumption; Benefits from FDI happen faster for countries with higher technology absorptive capacities;
Albulescu et al., (2019)	1980-2010	14 Latin American countries	Panel Quantile regression analysis	FDI has no clear impact on pollution
Demena & Afesorgbor (2019)	Not applicable	65 primary studies	Meta-analysis	An inverse relationship between FDI and emissions: an increase in FDI reduces pollution, supporting pollution halo hypothesis for developed countries; The quality of FDI inflow to developing countries is lower compared to FDI that goes to developed countries, supporting PHH.
Dong et al., (2019)	2002-2015	China regions	FGLS	FDI conserves energy in high-income regions, but there is no evidence supporting that FDI inflows increase energy consumption in low- and middle-income regions.
Dou & Han, (2019)	2000-2015	30 provinces, municipalities, and autonomous regions (except Tibet) of China.	Dividing industries into strongly and weakly mobile; Mediation model	Strongly mobile pollution industries tended to be transferred to areas with more relaxed regulations, which supports PHH.

Haug & Ucal (2019)	1974-2014	Turkey	ARDL; Non-linear ARDL	FDI increases CO_2 emissions in the long-run.
Shahbaz et al., (2019)	1990-2015	The Middle East and North African (MENA)	GMM	N-shaped association is validated between FDI and carbon emissions.
Shen et al., (2019)	2001-2014	Guangdong's 21 administered cities: 9 cities in the Pearl River Delta (PRD), and 12 cities in the Peripheral Non-Pearl River Delta (NPRD) area.	DEA; PMG/ARDL	Pollution transfer by the migration of pollution-intensive industries from the PRD to the NPRD region that supports PHH.
Xu et al., (2019)	2006-2016	China: east, central, and west regions	STIRPAT model	FDI reduces air pollutants.
Bildirici & Gokmenoglu (2020)	1975-2017	9 countries: Afghanistan, Iraq, Nigeria, Pakistan, Philippines, Syria, Somalia, Thailand and Yemen	Panel cointegration tests; ANOVA tests, long-run estimators, and panel trivariate Causality tests	FDI causes CO_2 emissions in the short-run; In the long-run, there is bidirectional causality between FDI and CO_2 emissions; FDI concentration on high-emissions industries.
Essandoh et al., (2020)	1991-2014	52 countries	PMG-ARDL	FDI transfer high emission-intensive production units from developed to developing countries, decreasing pollution in the developed countries thus increasing in the developing countries.
Xie et al., (2020)	2005-2014	11 emerging countries (Argentina, Brazil, China, India, Russia, South Korea, Mexico, Turkey, Indonesia, South Africa, and Saudi Arabia)	Extended (PSTR) with nonlinear and dynamic features	FDI ascend CO_2 emissions concentrations; the Spillover effect through economic growth suggests that FDI can decrease CO_2 emissions. FDI has a "W+V-shaped" temporal effect in carbon emissions.
Zhou et al., (2020)	2005-2015	47 cities in the Bohai Rim	OLS; GMM; Panel quantile regression	FDI has a positive influence on eco-efficiency (with carbon emissions as the undesired output).

Notes: ARDL- Autoregressive Distributed Lag; FGLS- Feasible Generalized Least Squares; FMOLS- Fully Modified Ordinary Least Squares; GMM- Generalized Method of Moments; IOA- Input-output analysis; MG- Mean Group; OLS- Ordinary Least Squares; PMG- Pooled Mean Group; PSTR- Panel Smooth transition regression; STIRPAT- Stochastic Impacts by Regression on Population, Affluence and Technology; VECM- Vector error correction model.

To analyze the whole impact of FDI on the environment, it is crucial to consider variables that represent specific characteristics of the host countries, complemented with a transverse consideration of impacts in time. The ARDL is used to divide the impacts into the short- and long-run. To better understand the entry of FDI into host countries, this paper empirically considers the level of innovation, efficiency, and regulation levels in countries, thus filling an important gap in the literature. The source country evaluates specific features of a country before providing investment there; these are considered in this paper. Countries that want to transfer polluting industries will check if the environmental stringency is lower in the host country. However, countries that want to diffuse global technology access, transferring their green technologies to another country, will check the efficiency, and innovation skills of host countries.

Once the transference of polluting industries happens among countries with different development and income levels, countries are divided into their income levels to improve the inquiry of this transference. Furthermore, the analysis of the industry sector produces better evidence of PHH and could provide a robustness check. Policymakers ought to realize that policies directly related to FDI should be debated considering that they do not have only effects of FDI, but also on the environment.

3. Data and methodology

In this work, a panel of 21 countries was studied, namely: Argentina, Austria, Bulgaria, Croatia, the Czech Republic, France, Germany, Greece, Hungary, Ireland, Japan, the Netherlands, Norway, Peru, Philippines, Portugal, Romania, South Africa, Spain, Turkey, and the United Kingdom. The period ranges from 2001 to 2017. The sample was selected according to the availability of data to handle a larger panel as possible. The environmentally related tax revenue variable has a lower availability of low-middle and upper-middle countries, as the industrial production does. These variables reduced the number of countries under scrutiny, mainly related to middle-income countries. The countries were divided into their income levels, high and middle, according to the World Bank's classification (see more in Table Appendix 1 (A1)). Given the restricted availability of variables to lower-middle-income and upper-middle-income countries, both the upper- and lower-middle countries were combined in the same group.

Table 2. Variables description

Variables	Definition	Sources
CO_2	CO_2 emissions in tonnes per capita	IEA
CO_2I	CO_2 emissions from industry in million tonnes	IEA
FDI	FDI inward stock in millions of USD	UNCTAD
GFCF	Gross fixed capital formation in constant 2010 USD	WB
TO	Trade as a share of Gross Domestic Product	WB
EF	Energy efficiency index – Calculated using equation 1	IPI (WB)
		Energy (IEA)
PAT	Patent applications for residents	WB
REG	Environmentally related tax revenue as a share of Gross Domestic Product	OECD stat

The efficiency level of the countries has relevance to evaluate the impacts of FDI, as previously stated. In this work, the energy efficiency index represents the industrial efficiency of the countries and was calculated through equation (1). This concept was developed by Patterson (1996) and reveals how many units of input are necessary to produce an output unit (Marques et al., 2019).

$$EF = \frac{Output}{Energy} \tag{1}$$

Industrial production is used as a proxy of the Industrial Production Index (IPI) to represent the output. Energy consumption from industry in kWh is also used. Recent studies stated that the incorporation of energy consumption in CO_2 emissions regressions could produce biased results (Jaforullah & King, 2017), and for that reason, the use of energy efficiency seems to be more suitable.

As a proxy of environmental pollution, CO_2 emissions are used as is commonly found in the literature. CO_2 emissions from the industry sector represent the environmental pollution derived from the industry sector. Gross fixed capital formation (GFCF) was used as a proxy of a countries' economic performance. GFCF could be related to capital intensive industries, as an increase in the capital in a production process generally consumes more energy which could, in turn, increase pollution (Sapkota & Bastola, 2017). Trade (TO) performs trade openness as is usual in the literature (e.g., Essandoh et al., 2020; Sbia et al., 2014), and has a higher correlation with FDI, and also Granger Causality, which means that trade could be related to FDI, without a doubt. Environmentally related tax revenue (REG) is used as a proxy for environmental regulation (Hashmi & Alam, 2019). Environmental regulations could stimulate innovation as stated by the literature (Kneller & Manderson, 2012; Lee et al., 2011; Johnstone et al., 2010), which could mean that countries with a high level of innovation do not allow the entry of polluting and inefficient industries. For that, patents (PAT) are used to measure the innovation level of the countries (Burhan et al., 2017).

All numerical variables are converted into *per capita*, and then into natural logarithms. The variables TO and REG, once they are in a share of Gross Domestic Product, are directly converted into natural logarithms. The descriptive statistics of the variables are shown in Table A2.

3.1. Preliminary tests

Preliminary tests were carried out to assess the presence of multicollinearity, collinearity, and the cross-sectional dependence of variables. To do that, correlation matrices, VIF, and cross-sectional dependence tests were used.

Table 3. Correlation matrices and VIF statistics (high-income countries)

	LCO₂	***LFDI***	***LY***	***LE***	***LTO***	***LPAT***	***LREG***		***DLCO₂***	***DLFDI***	***DLY***	***DLE***	***DLTO***	***DLPAT***	***DLREG***
LCO₂	1.000							***DLCO₂***	1.000						
LFDI	0.044	1.000						***DLFDI***	0.073	1.000					
LY	0.423	0.378	1.000					***DLY***	0.353	0.229	1.000				
LE	0.156	0.472	0.690	1.000				***DLE***	-0.033	0.185	0.154	1.000			
LTO	0.069	0.688	-0.111	0.059	1.000			***DLTO***	0.187	-0.088	0.171	0.192	1.000		
LPAT	0.384	-0.245	0.503	0.477	-0.458	1.000		***DLPAT***	0.080	0.033	-0.143	-0.019	-0.071	1.000	
LREG	-0.015	0.322	-0.285	-0.402	0.552	-0.482	1.000	***DLREG***	-0.038	-0.083	-0.351	-0.122	-0.054	-0.025	1.000
VIF		4.71	2.68	3.77	3.04	2.48	2.21			1.12	1.28	1.10	1.09	1.03	1.15
VIF_{MEAN}				3.15								1.13			
Cross-sectional dependence															
CD-test	25.49***	29.06***	10.21***	17.02***	25.91***	4.10***	5.49***		9.86***	16.82***	14.55***	0.49	22.29***	0.76	3.79***

Table 4. Correlation matrices and VIF statistics (middle-income countries)

	LCO₂	***LFDI***	***LY***	***LE***	***LTO***	***LPAT***	***LREG***		***DLCO₂***	***DLFDI***	***DLY***	***DLE***	***DLTO***	***DLPAT***	***DLREG***
LCO₂	1.000							***DLCO₂***	1.000						
LFDI	0.648	1.000						***DLFDI***	0.205	1.000					
LY	0.648	0.793	1.000					***DLY***	0.447	0.306	1.000				
LE	-0.725	-0.214	-0.076	1.000				***DLE***	0.109	-0.102	0.004	1.000			
LTO	0.086	0.197	0.022	0.016	1.000			***DLTO***	0.157	-0.222	0.058	0.335	1.000		
LPAT	0.573	0.192	0.503	-0.271	-0.167	1.000		***DLPAT***	0.111	-0.011	0.073	-0.016	0.049	1.000	
LREG	0.768	0.558	0.725	-0.387	0.183	0.429	1.000	***DLREG***	-0.057	0.080	-0.138	0.031	-0.127	-0.109	1.000
VIF		4.54	8.54	1.90	1.28	1.95	3.37			1.19	1.16	1.14	1.21	1.02	1.06
VIF$_{MEAN}$				3.60								1.13			
Cross-sectional dependence															
CD-test	2.37**	17.55***	15.86***	4.56***	2.41**	-2.44**	2.54**		2.90***	5.21***	6.72***	-0.26	8.94***	-1.13	2.99***

Cross-sectional dependence (CD) must be checked in panel data studies since, if it is present, this means that countries are no longer independent observations, but affect each other's outcomes; this must be corrected once can produce misleading results as stated by De Hoyos & Sarafidis (2006). The null hypothesis of the cross-sectional dependence test proposed by Pesaran (2004) is cross-sectional independence. Tables 3 and 4 reveal that none of these phenomena are a concern. First-generation unit root tests could be inefficient to assess the order of integration of the variables in the presence of individual CD as announced by Pesaran (2007).

Table 5. Panel Unit Root tests

	High income					**Middle income**				
	CIPS (Zt-bar)		**Maddala-WU**		**Levin-Lin-Chu**	**CIPS (Zt-bar)**		**Maddala-WU**		**Levin-Lin-Chu**
	without trend	with trend	without trend	with trend		without trend	with trend	without trend	with trend	
LCO2	-1.49*	0.29	10.20	37.09*	0.73	2.44	1.41	30.71**	18.18	-1.66**
LCO2I	-4.73***	-4.94***	19.12	103.60***	-1.88**	-0.42	0.88	18.19	20.97	-0.93
LFDI	0.35	-1.14	54.96***	20.04	-4.64***	0.26	-0.21	51.69***	15.41	-3.41***
LY	1.44	-1.38*	36.12*	38.29*	-3.48***	1.91	2.19	38.16***	12.56	-2.76***
LTO	0.28	1.09	20.52	53.63***	-3.03***	1.16	2.34	15.74	20.86	-1.44*
LEF	-2.38***	-1.70**	28.17	78.52***	-2.60***	0.42	2.23	22.74	20.77	-0.65
LPAT	1.52	0.47	27.34	26.62	-0.36	-0.92	-1.16	13.12	21.61	-1.51*
LREG	2.05	3.09	20.71	19.84	-0.17	-0.27	-1.70**	39.29***	41.99***	-2.89***
DLCO2	-4.83***	-3.98***	98.32***	83.95***	-5.66***	-2.09**	-2.53***	74.83***	77.95***	-5.62***
DLCO2I	-5.94***	-3.70***	183.33***	137.26***	-10.10***	-1.69**	-3.18***	60.51***	44.91***	-5.42***
DLFDI	-3.17***	-1.73**	75.21***	93.35***	-5.47***	-2.51***	-1.26	32.95***	31.56**	-1.76**
DLY	-3.18***	-1.35*	73.10***	44.85**	-5.44***	-1.75**	-2.18**	29.68**	32.52***	-3.09***
DLTO	-1.61*	-1.29*	118.27***	75.00***	-7.93***	-0.53	0.59	64.61***	45.17***	-3.97***
DLEF	-5.41***	-4.44***	166.31***	126.11***	-8.62***	-1.33*	-0.57	62.10***	44.19***	-4.11***
DLPAT	-3.77***	-3.20***	105.95***	91.93***	-5.11***	-3.82***	-2.85***	69.44***	51.54***	-5.03***
DLREG	0.11	0.11	53.94***	41.68**	-3.76***	-4.21***	-2.67***	105.81***	85.55***	-7.68***

Notes: ***,**, * denote statistical significance at 1%, 5%, 10% level, respectively.

Then, the first-generation unit root tests (Levin et al., 2002; Maddala & Wu, 1999) and the second-generation unit root test cross-sectional augmented IPS (CIPS) (Pesaran, 2007) were carried out as Shahbaz et al., (2015) do (see Table 5), suggesting that all – this means, I(0) - and on their first differences – I(1) –, which reinforce the use of the ARDL model. It is crucial to verify if none of these variables are I(2).

3.2. Method

The ARDL model was proposed by Pesaran et al., (2001). The main motivation for the use of this methodology is that it allows an analysis of the dynamic effects of the variables, by analysing effects in the short- and long-run. The specification of the ARDL model is the following:

$$LCO2_{it} = \alpha_{1i} + \delta_{1i}TREND + \beta_{1i1}LCO2_{it-1} + \beta_{1i2}LFDI_{it} + \beta_{1i3}LFDI_{it-1} + \beta_{1i4}LGFCF_{it} + \beta_{1i5}LGFCF_{it-1} + \beta_{1i6}LTO_{it} + \beta_{1i7}LTO_{it-1} + \beta_{1i8}LEF_{it} + \beta_{1i9}LEF_{it-1} + \beta_{1i10}LPAT_{it} + \beta_{1i11}LPAT_{it-1} + \beta_{1i12}LREG_{it} + \beta_{1i13}LREG_{it-1} + \mu_{1it} \quad (2)$$

To capture the dynamic relationships between variables, the equation (2) was reparametrized to the following equation:

$$DLCO2_{it} = \alpha_{2i} + \delta_{2i}TREND + \beta_{2i1}DLFDI_{it} + \beta_{2i2}DLGFCF_{it} + \beta_{2i3}DLTO_{it} + \beta_{2i4}DLEF_{it} + \beta_{2i5}DLPAT_{it} + \beta_{2i6}DLREG_{it} + \gamma_{2i1}LCO2_{it-1} + \gamma_{2i2}LFDI_{it-1} + \gamma_{2i3}LGFCF_{it-1} + \gamma_{2i4}LTO_{it-1} + \gamma_{2i5}LEF_{it-1} + \gamma_{2i6}LPAT_{it-1} + \gamma_{2i7}LREG_{it-1} + \mu_{2it} \quad (3)$$

The prefix "D" represents the first differences of variables, and "L" the natural logarithm. α is an intercept. β are the short-run coefficients of the explanatory variables, γ are the long-run outputs, t refers to the analysing period in years, i represents the cross (countries), and μ is the error term. The $LCO2_{it-1}$ represents the Error Correction Mechanism (ECM), that is, the long-run coefficient of the lagged dependent variable.

3.3. Diagnostic tests

To avoid biased results, the Robust Hausman test was carried out (see, e.g., Neves et al., 2017) with 20 bootstrap repetitions to check the presence of the individual effects of countries. This test was carried out instead of the traditional Hausman test since it is more appropriate in the presence of heteroscedasticity and/or serial correlation (Neves et al., 2017). The result shows that the fixed effects estimator is suitable to use, and it also highlights the existence of individual effects. Moreover, three diagnostic tests were carried out, upon the residuals, and revealed in this section to go further into the analysis of the data's characteristics, namely: (i) the Modified Wald test to verify the existence heteroskedasticity with the null hypothesis of homoscedasticity; (ii) the Breusch Pagan LM test to analyse the cross-sectional correlation with the null hypothesis of cross-sectional independence; and (iii) the Wooldridge to test the existence of first-order serial autocorrelation with the null hypothesis of no first-order serial autocorrelation.

Table 6. Diagnostic tests

	High-income	Middle-income
Robust Hausman test	60.88***	77.80***
Wooldridge test	58.935***	40.230***
Breusch Pagan LM	176.260***	32.149
Modified Wald test	47.33***	33.70***

Notes: *** denotes significance at 1% level. The null hypothesis for the Robust Hausman test is "difference in coefficients is not systematic".

The existence of cross-section dependence, first-order serial correlation, and heteroscedasticity in the high-income countries model allows the use of the Driscoll & Kraay (1998) estimator (DK), as this estimator produces robust standard errors with these characteristics and allows the utilization of fixed effects (Neves et al., 2017). The DK was also used in the middle-income countries model.

4. Results and discussion

This section is compounded by three subsections. The first two reveal the results and discussion for both overall CO_2 emissions and CO_2 emissions from the industry sector. The majority of the results from the model of CO_2 emissions from the industry sector supports the ones from overall CO_2 emissions, which provides a robustness check. Furthermore, the analysis of the industry sector provides useful additional information about the impacts of the innovation and regulation levels of this sector that deserves more attention; This debate was further explored in the final subsection of comparison between models.

Table 7. Zivot and Andrews unit root test

	Trend	Break point	Intercept	Breakpoint	Both	Breakpoint
High-income						
Hungary						
LCO_2I	-5.020***	2004	-4.158	2009	-6.687***	2005
$DLCO_2I$	-5.835***	2006	-7.286***	2010	-7.678***	2010
LFDI	-1.705	2013	-2.150	2014	-1.943	2007
DLFDI	-6.213***	2005	-6.183***	2011	-7.048***	2015
LGFCF	-7.368***	2008	-3.888	2006	-7.254***	2007
DLGFCF	-4.126*	2011	-5.561***	2008	-5.202	2008
LTO	-3.929	2007	-4.572	2009	-9.733***	2009
DLTO	-4.289*	2004	-5.611***	2009	-5.058*	2009
LE	-4.797**	2005	-4.517	2004	-4.505	2006
DLE	-5.815***	2007	-7.090***	2010	-7.207***	2010
LPAT	-2.489	2006	-3.612	2011	-3.026	2007
DLPAT	-6.424***	2013	-7.821***	2010	-7.526***	2010
LREG	-4.469**	2014	-3.046	2008	-4.392	2012
DLREG	-4.464**	2009	-5.202**	2015	-4.250	2005
Norway						
LCO_2	-4.052	2011	-4.184	2013	-4.257	2010
$DLCO_2$	-8.028***	2014	-8.593***	2015	-8.051***	2013
LCO_2I	-5.020***	2004	-4.158	2009	-6.687***	2005
$DLCO_2I$	-5.835***	2006	-7.286***	2010	-7.678***	2010
LFDI	-1.705	2013	-2.150	2014	-1.943	2007
DLFDI	-6.213***	2005	-6.183***	2011	-7.048***	2015
LGFCF	-7.368***	2008	-3.888	2006	-7.254***	2007
DLGFCF	-4.126*	2011	-5.561***	2008	-5.202**	2008
LTO	-3.929	2007	-4.572	2009	-9.733***	2009
DLTO	-4.289*	2004	-5.611***	2009	-5.058*	2009
LE	-4.797**	2005	-4.517	2004	-4.505	2006
DLE	-5.815***	2007	-7.090***	2010	-7.207***	2010
LPAT	-2.489	2006	-3.612	2011	-3.026	2007
DLPAT	-6.424***	2013	-7.821***	2010	-7.526***	2010
LREG	-4.469**	2014	-3.046	2008	-4.392	2012
DLREG	-4.464**	2009	-5.202**	2015	-4.250	2005
Portugal						
LCO_2	-3.710	2014	-1.654	2010	-3.923	2014
$DLCO_2$	-6.604***	2012	-7.027***	2015	-6.696***	2015
LFDI	-4.872**	2010	-3.700	2006	-4.442	2009
DLFDI	-5.326***	2012	-7.450***	2010	-8.297***	2010
LGFCF	-1.991	2005	-3.691	2011	-2.268	2011
DLGFCF	-3.197	2013	-2.818	2009	-4.097	2011
LTO	-3.464	2010	-4.761*	2009	-4.604	2009
DLTO	-4.391*	2004	-4.558	2011	-4.468	2011
LE	-3.294	2011	-3.113	2009	-2.913	2010
DLE	-4.696**	2009	-6.531***	2012	-6.228***	2012
LPAT	-2.054	2012	-2.408	2008	-2.379	2008
DLPAT	-4.532**	2009	-3.979	2005	-5.707***	2010
LREG	-5.160***	2013	-2.000	2014	-5.228**	2012

DLREG	-4.182*	2009	-5.088**	2013	-4.211	2008
Spain						
LCO_2	-2.356	2014	-3.829	2009	-2.398	2013
$DLCO_2$	-4.606**	2010	-4.291	2008	-4.757	2008
LFDI	-3.966	2008	-4.868**	2006	-4.132	2007
DLFDI	-4.068	2015	-3.711	2005	-3.907	2015
LGFCF	-2.631	2014	-4.068	2009	-2.099	2005
DLGFCF	-3.616	2010	-3.672	2008	-5.171**	2009
LTO	-3.355	2010	-3.268	2008	-4.322	2009
DLTO	-3.568	2004	-4.706*	2010	-4.501	2010
LE	-2.839	2014	-3.593	2006	-3.933	2006
DLE	-4.471**	2007	-4.458	2006	-5.273**	2007
LPAT	-2.815	2011	-0.466	2007	-2.840	2011
DLPAT	-3.769	2009	-3.502	2006	-3.805	2010
LREG	-3.701	2010	-5.662***	2013	-4.728	2013
DLREG	-4.201*	2014	-4.935*	2010	-5.991***	2013
Middle-income						
Bulgaria						
LCO_2	-3.853	2008	-3.745	2013	-4.121	2009
$DLCO_2$	-7.306***	2015	-7.195***	2009	-7.019***	2008
LCO_2I	-2.359	2014	-3.183	2009	-2.507	2009
$DLCO_2I$	-4.605**	2010	-4.296	2008	-4.756	2008
LFDI	-7.496***	2008	-2.532	2006	-6.419***	2007
DLFDI	-2.760	2015	-3.556	2008	-3.140	2008
LGFCF	-3.195	2007	-2.761	2005	-4.194	2009
DLGFCF	-3.179	2011	-5.968***	2009	-5.856***	2009
LTO	-3.173	2007	-2.999	2004	-4.874*	2009
DLTO	-3.593	2010	-4.108	2011	-3.923	2011
LE	-4.548**	2010	-5.475***	2009	-5.310**	2009
DLE	-6.299***	2004	-8.123***	2010	-7.847***	2010
LPAT	-4.195*	2008	-4.863**	2011	-4.689	2009
DLPAT	-8.309***	2014	-9.518***	2008	-9.132***	2008
LREG	-4.645**	2004	-2.886	2009	-3.896	2009
DLREG	-5.627***	2006	-6.013***	2005	-5.568**	2007

Note: the lag selection criteria of Zivot and Andrews test is based in a TTest; ***, **, and *, denote statistical significance at 1%, 5%, and 10% level, respectively.

The long-run elasticities come from the ratio between the coefficient of the respective variable and the ECM; both lagged once, and this ratio posteriorly multiplied by -1. The socio-economic context of the countries is considered and controlled through the inclusion of impulse dummies. The non-consideration of socio-economic events could produce misleading results. As such, the Zivot & Andrews (1992) (ZA) unit root test was performed to verify the existence of structural breaks and are presented in Table 7.

Table 8. Test of overall significance

	Overall CO_2 emissions	CO_2 emissions from the industry sector
High-income countries	F(3,178)=7.74***	F(2,179)=19.49***
Middle-income countries	F(1,105)=10.49***	F(1,105)=25.15***

Note: *** denotes significance at 1% level. H0: var=0

Together with the analysis of the ZA test, the analysis of the socio-economic context of the countries, and the analysis of the residuals, the milestones were identified and considered. Furthermore, the test of overall significance was carried out with the null hypothesis of the coefficients of dummies are equal to 0 (see Table 8).

4.1. General CO_2 emissions

Following the United Nations Framework Convention on Climate Change (UNFCCC), Norway registered, in 2010, an increase of 33% in its CO_2 emissions, compared to 1990. In 2010, Portugal installed 10% more renewable energy capacity, and its emissions reduced by 5.5%. Referring to Statistics Portugal (INE)[5], Portugal registered 44 green patents that year. These improvements are allied to the first commitment period of the Kyoto protocol. Bulgaria was considered the economy with the highest level of energy intensity by the European Commission[6] in 2010. In 2011, Bulgaria further raised its energy consumption. Considering what is stated in the UNFCCC inventory[7], more than half of the emissions from Bulgaria are related to energy supply. From 2000, emissions in Bulgaria started to rise, and in 2011 reached 1990 levels of pollution. Spain dealt with an economic crisis in 2013, which could explain the slowdown in emissions.

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[5] https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOEStipo=ea&PUBLICACOEScoleccao=107664&selTab=tab0&xlang=pt, 23 February 2019

[6] https://ec.europa.eu/clima/sites/clima/files/strategies/progress/reporting/docs/bg_2014_en.pdf, 23 February 2019

[7] https://unfccc.int/sites/default/files/resource/Bulgaria%20bg_br2.pdf, 23 February 2019

Table 9. Estimation results with overall CO_2 emissions

Dependent Variable: DLCO2	**High-income**	**Middle-income**
Short-run semi-elasticities		
Constant	-0.5168	-0.9370***
TREND	-0.0036*	0.0015**
DLFDI	-0.0278*	0.0314**
DLGFCF	0.2330***	0.2175***
DLTO	0.1468***	0.1267**
DLEF	-0.0761*	-0.0021
DLPAT	0.0322	0.0213*
DLREG	0.1357*	0.0125
Computed long-run elasticities		
LCO2 (-1) (ECM)	-0.2673***	-0.3328***
LFDI (-1)	-0.1322001*	-0.0939073***
LGFCF (-1)	0.3371335***	0.3577464***
LTO (-1)	0.2391416**	0.0355411
LEF (-1)	-0.241319***	-0.1536185**
LPAT (-1)	0.0547018	0.0982878***
LREG (-1)	-0.1431193	-0.1407706**
NO2010	0.0685***	
PT2010	-0.1176***	
BG2011		0.1459***
ES2013	-0.1042***	
Diagnostic statistics		
N	208	128
R^2	0.4088	0.4733
F	F(17, 15)=861.81	F(15, 15)= 485535.22

Notes: ***, **, * denote statistical significance at 1%, 5%, 10% level, respectively.

Both in the short- and long-run, gross fixed capital formation increases pollution for high-income and middle-income countries. This finding is not unexpected. As stated by Sapkota & Bastola (2017), an increase in the capital level of a production process will consume more energy, leading to an increase in pollution. It could also be related to the scale effect of production, in such a way that an increase in investment will increase production and energy consumption. This finding awakes for the debate about the energy sources. If an increase in energy consumption leads to an upsurge in pollution, this could suggest that these countries are not using enough renewable energy sources (RES), a factor that could help in reducing emissions (e.g., Ben Jebli & Ben Youssef, 2015; Apergis & Payne, 2012). The high demand for energy in high-incomecountries make them recur to the dirty sources, which means that these countries must improve their RES capacity.

Trade openness is contributing to environmental degradation, which could be linked to exports of energy-intensive goods that increase energy consumption (Sbia et al., 2014), which consequently increases pollution (Sun et al., 2017). The debate about energy sources comes up again. Energy efficiency can help in reducing emissions over time in high-income countries, but it is only effective in reducing pollution in the long-run in middle-income countries. Less energy consumed per unit produced indicates a more efficient country. For the environmentally related tax revenue, the study shows an unanticipated result. As a proxy of environmental regulation, this variable is expected to contribute to reducing CO_2 emissions. Contrariwise, it appears that, in the period under analysis, regulation increases pollution in the short-run in high-income countries. Firms want to maximize their profits, which means that they will pay extra taxes to pollute more. However, it only happens until the turning point when it is more countervailing to pay extra environmental taxes than to invest in research and development (R&D). This outcome could mean that these environmental taxes are not a good instrument to help in reducing emissions in the short-run. For middle-income countries, environmental regulations seem to decrease emissions as they are supposed to do. This effect does not mean that environmental regulation is more effective in middle-income countries. Even though regulation decreases pollution in the long-run, the implementation of new environmental laws does not have enough effect in the short-run.

Regarding patents, they do not reveal to be statistically significant in the high-income countries model, which is also unforeseen considering the higher levels of human capital and R&D expenditures that are a feature in these countries. For instance, countries develop new technologies (and register their intellectual property) with the specific aim of decreasing pollution. This unexpected effect could have an inherent connection with a decrease in the number of patents as explained by Su & Moaniba (2017). It does not mean that these countries decrease their environmental concerns but that they apply new technologies that decrease emissions until a certain level, suspending thereafter further research to develop new technologies. Contrariwise, middle-income countries seem to develop new patents directionally related to their economic growth to grow as faster as possible with lower costs. The significant obstacles that exist in the transfer of carbon mitigation technologies that are usually developed by high-income countries (Cheng et al., 2019), could also explain this negative effect.

High-income countries are benefiting from FDI as it reduces CO_2 emissions, both in the short- and long-run, which supports the Pollution Halo Hypothesis. Countries under analysis are furthering from the transfer of "know-how" and new management techniques, green technology, and the introduction of new and eco-friendly machines, for example. This transference has a strong linkage with their high environmental stringency and efficiency, policies that do not allow the entry of dirty FDI. One observes that in middle-income countries, the effect of FDI changes through the short- and long-run. FDI causes an increase in pollution in the short-run while decreases it in the long-run. The short-run effect supports the PHH. Polluting industries could be transferred from high-income countries to middle-income countries to avoid an increase in environmental compliance costs since middle-income countries generally have more relaxed environmental regulations. However, in the long-run, FDI decreases emissions. At an initial point, the effect that FDI has on the environment depends on the environmental awareness, economic development level, and mainly the technology absorptive capacity of countries. This capacity reflects the ability of countries to learn quickly, such as noted by Adom et al., (2019). Even if high-income countries want to transfer their eco-friendly technologies through FDI, if the host countries have a lower absorptive capacity, the effect will happen gradually, increasing their adjustment costs (Adom et al., 2019).

In brief, middle-income countries could be receiving both dirty and clean FDI. In the short-run, clean FDI does not improve the environment due to the lower technology absorptive capacity of middle-income countries. However, in the long-run, these countries seem to engage the new technologies and techniques, applying foreign knowledge in their domestic firms, consequently decreasing pollution. To check the robustness of the results, since the transference of polluting industries among countries are expected to have more impact directly in CO_2 from the industry sector, evaluating the impacts that FDI has directly on CO_2 from the industry sector and not as a whole on the economy was required.

4.2. CO_2 emissions from the industry sector

The impact that FDI has on CO_2 emissions could be due to the impact on energy consumption by increasing industrial activities, such as stated by Salim et al., (2017). Furthermore, as previously stated, the main objective of this paper is the analysis of the transference of polluting industries across countries through FDI, as this transference does not embody environmental improvements, only a reallocation of emissions sources. For that, the analysis of the impacts on emissions from the industry sector is required. All tests previously explained were also carried out (see Tables A3 to A5). The socio-economic context is also considered, giving special attention to the industry sector (see Tables 7 and 8).

A more in-depth analysis of several countries' idiosyncrasies shows that in 2003, for example, the oil price provoked a favourable shock in demand in Norway, which increased oil investment and fiscal receipts. This shock could be responsible for the 26% growth in emissions in 2003, compared to 1990. In 2009 Bulgaria faced a difficult year. In addition to the global economic crises, gas supply was cut during the Russia-Ukraine gas dispute. Moreover, the production of industrial minerals, such as cement, for example, registered a significant decrease, accompanied by a significant reduction of refined lead exportations according to International Business Publications[8]. These changes are reflected in a decrease

8 https://books.google.pt/books/about/Bulgaria_Mineral_Mining_Sector_Investmen.html?id=aE5mLBMlegoC&redir_esc=y, 23 February 2020

in industrial production along with emissions from the industry sector. Hungarian Central Statistical Office[9] stated that in 2001 a substantial increase in the external trade of transport equipment arose. In this year, the gross fixed capital formation rose by 1.7%, and the industrial performance reached an increase in its volume of 5.7%, which explains the substantial emissions.

Table 10. Estimation results with CO_2 from the industry sector

Dependent Variable: DLCO2I	**High-income**	**Middle-income**
Short-run semi-elasticities		
Constant	-8.6219***	-9.5393***
TREND	-0.0037	-0.0052**
DLFDI	0.0152	0.1111***
DLGFCF	0.4275***	0.3105***
DLTO	0.4970***	0.1918**
DLEF	-0.9623***	-0.5006***
DLPAT	-0.0482	0.0393
DLREG	0.0516	0.0177
Computed long-run elasticities		
LCO2I (-1) (ECM)	-0.4162***	-0.4614***
LFDI (-1)	-0.0793348***	-0.0888268
LGFCF (-1)	0.4803342***	0.4221049***
LTO (-1)	0.5149368***	-0.0049962
LEF (-1)	-1.201056***	-0.6925967***
LPAT (-1)	-0.0187535	0.0339532
LREG (-1)	0 .0964195	0.0509319
NO2003	0.2988***	
BG2009		-0.8306***
HU2011	0.2909***	
Diagnostic statistics		
N	208	128
R^2	0.6411	0.4215
F	F(16, 15)=1074852.79	F(15, 15)=7756.23

Notes: ***, ** denote statistical significance at 1%, 5% level, respectively

Both gross fixed capital formation, and trade openness increase pollution, both in high- and middle-income countries. Energy efficiency enhances environmental quality and defines the environmental performance of the industry sector across countries. Both patents and environmental regulations are not shown to be statistically significant in explaining emissions from industry neither in high- and middle-income countries. This absence of statistical significance could mean that governments are not paying enough attention to increasing innovation in the industry sector and that they are not thinking about the pollution that is emitted from this sector, as well.

[9] https://www.ksh.hu/docs/hun/xftp/idoszaki/mo/hungary2011.pdf, 23 February 20

One observes that FDI presents different statistical significances degrees in the short- and long-run. As detailed by Baek (2015), FDI could be considered as a long-run phenomenon, but in the short-run, the introduction of new technologies may not be enough to mollify the negative impacts that FDI has on pollution (Shahbaz et al., 2019). As such, FDI causes a decrease in CO_2 emissions from the industry sector in high-income countries, and it increases in middle-income countries. These results also support the PHH for middle-income countries.

4.3. Overall comparison and discussion

This elucidates the impacts of FDI on the environment and confronts two dimensions of this relationship: overall CO_2 emissions and CO_2 emissions from the industry sector. Overall, the results reveal high consistency, not only when considering the literature but also between each other. One observes that gross fixed capital formation and trade openness should be treated as the main drivers of pollution, probably due to them causing an increase in energy consumption. The use of RES helps in reducing emissions (Ben Jebli & Ben Youssef, 2015), which reveals that these countries are not using enough RES to fill energy demand. Given that energy efficiency should help in reducing emissions, these countries must rethink their environmental regulations related to energy production sources to make countries move away from fossil fuels.

At the same time, the policymakers should encourage investment in R&D to increase the efficiency of the industry sector in these countries, decreasing their energy consumption per unit of output, consequently decreasing CO_2 emissions. The impact of regulation is surprising; it increases pollution in high-income countries. This can be explained by the fact that some firms are prepared to pay extra taxes to pollute rather than invest in innovation. These countries must apply different policy tools, experimenting with different taxes and subsidies. Contrariwise, middle-income countries are getting a decrease in pollution through the implementation of environmental regulations. However, when countries are still increasing their pollution through the development of new patents to increase their income, this is because they are doing so with lower costs as possible, laying aside environmental concerns.

One observes that FDI improves environmental quality in high-income countries, while it harms in middle-income countries in the short-run. However, in the long-run FDI could help middle-income countries in reaching their emissions targets. These opposite effects reveal that middle-income countries have lower levels of technology absorptive capacity. Even with these dichotomous effects in high-income countries and middle-income countries, there is a certainty about the transference of polluting industries across countries; however, the positive effect in the long-run could provoke some doubts. Broadly speaking, middle-income countries receive new technology and must absorb and apply that in their industries to increase the technique effect influence. The results from general CO_2 emissions support that this absorption is happening although very slowly. However, regarding the industry sector, the FDI impacts their emissions only in the short-run, which means that they are not applying and absorbing enough green technology to benefit from the phenomenon, as high-income countries do. As a result, the Pollution Halo Hypothesis is supported for high-income countries, and the PHH is sustained for middle-income countries.

Although high-income countries are increasing their external dependency by importing final energy-intensive goods, it is more profitable as they avoid environmental regulation. Notwithstanding, this only happens because middle-income countries have lower environmental regulation levels. The shift of FDI away from the industry sector should not be an option since it could lead to deindustrialization (Doytch & Uctum, 2011), which means that environmental policies encouraging clean FDI are required to reach sustainable development (Essandoh et al., 2020). Granting this, these countries must rethink their regulation structure, encouraging investment in R&D and human capital development, as this can change their technology absorptive capacity, which would help them benefit from FDI. Without a sufficient level of this capacity, firms cannot apply foreign knowledge quickly, and the benefit will be lagged.

With higher levels of investment in R&D, countries will have more environmental consciousness and efficiency, and consequently, they will not allow entries of dirty FDI. Policymakers must pay more attention to the industry sector to encourage the development of green patents linked to industries, to increase their efficiency. Furthermore, policymakers should also increase their environmental stringency, especially concerning the entry of new industries. Moreover, increasing the stringency of the environmental regulation of these countries will help them to improve their environmental performance Different countries must have different policy setups to smooth and decrease environmental degradation as concluded by Soytas & Sari (2006a, 2006b).

It is of high relevance to accomplishing a logical linkage between outcomes. Once, trade openness was considered as a main driver of pollution, in middle-income countries, but it shows no statistical significance in the long-run. Middle-income countries may not have enough trade openness to have an impact on pollution in the long-run. Anyhow, a different explanation emerges. In the short-run, in an attempt to increase income, these countries increased their trade openness without major environmental concerns. This is reflected in the non-statistical significance of regulation in the short-run. At this moment, both FDI and trade openness increase pollution, which reveals the entrance of new polluting industries and the production of energy-intensive goods. Perhaps due to the pressure of international agreements in the long-run, these countries improved their environmental awareness and regulations to control pollutant emissions. To begin with, these countries have a comparative advantage for polluting industries, but as they raise their environmental stringency, foreign investments decrease. With this, there is also a decrease in the significance that trade openness has in the definition of emissions in these countries. The foreign investments that middle-income countries receive in the short-run are mainly due to the lower stringency of their environmental laws. But in the long-run, the increase in their environmental stringency makes efficiency matter more to FDI inflows and in helping in reducing emissions.

Finally, what if suddenly, unexpectedly, countries, no matter their income level, were all confronted by a symmetrical crisis? For example, a crisis resulting from a pandemic, like that of COVID-19. Generally, during an economic crisis, automatic stabilizers are triggered without additional efforts by governments to diminish its impacts, in an attempt to harmony the government budget balance. But they do not act during a symmetric crisis. International trade suffers, and the globalization reduces substantially, both reflected in tourism reduction, for example, and on flows of FDI. The main concern is whether a pandemic will have lasting impacts on globalization; something that cannot be answered yet. An optimist scenario would expect that in the post-crisis the international trade would return to pre-crisis levels presenting a V-shaped recovery, but this may not happen. The same is true for FDI flows.

This crisis, although symmetrical among countries, has greater consequences for less developed countries. For some countries, FDI is one of the major sources of income, productivity, and development. The consumption and the exportations highly reduced, the production stalled, and consequently, a sharp downward trajectory for these countries. This symmetrical crisis exposes the fragilities of the dominant strategy of exploiting the comparative advantages of countries, particularly in the production process. Besides the peak effect of pollution in countries with a comparative advantage in polluting industries, this exploitation also exposes the debilities, external exposure, and dependency of the countries.

Under economic uncertainty, multinational enterprises rethink their priorities, restricting capital expenditures related to foreign investments, delaying FDI flows, or even cancelling it. More developed countries are major sources of outbound FDI, which means that profits in their foreign affiliates will be substantially reduced. According the UNCTAD (2020b), FDI flows will be hitting their lowest level for the past two decades (UNCTAD, 2020a). This means that the effect of PHH will be "weakened", not because of stricter or more relaxed environmental regulations, but as a consequence of the reduction in FDI. Although less frequent, the transference of industries would be expected, but the source countries would switch their investment to closer countries. This will lead to changes in those countries most commonly targeted as recipients of FDI, which are generally less developed countries, and are extremely dependent on FDI inflows.

Countries must invest in R&D to increase innovation and efficiency, more than ever; as it can help in reducing their costs (both to help firms to reduce costs, and to decrease the necessary public health response costs). FDI is crucial to help middle-income countries to soften the pandemic crisis' impacts. Middle-income countries must not reduce their environmental standards to attract FDI, but they must further attract due to their higher labor force level, betting in an increase in its human development (investing more in R&D and reducing the uncertainty of corruption, health, and terrorism, for example). Furthermore, source countries of FDI must do an effort to transfer improved technologies and techniques to these countries, to have a bidirectional benefit: cheaper labor, reduced costs, and improved environmental quality worldwide. This constitutes a very interesting issue that ought to be deeply investigated in further research.

5. Conclusions and policy recommendations

This paper focuses on the analysis of the impact that FDI has on pollution. In this study, countries are divided into their income levels as the transference of polluting industries happens mainly between countries with different development and income levels. The ARDL model provides a useful disaggregation of the impacts, making it possible to better understand the impacts extended in time. This paper contributes to the enlargement of the literature about FDI-environment nexus with empirical evidence of a linkage between variables that could change impacts across time. Besides that, this paper innovates by considering factors as regulation, innovation, and efficiency levels in the countries under scrutiny. Furthermore, the discussion about overall emissions and those from the industry sector provides robust support for PHH in middle-income countries, while high-income countries benefit from FDI phenomenon. The technology absorptive capacity of the middle-income countries plays a critical role in analysing the impacts of FDI, although the positive effect of FDI in overall emissions happens slowly. The countries in this study are facing a trade-off between FDI and meeting pollution reduction targets. In this paper, policymakers gain useful guidance to help them understand that it is possible to increase the income of a country through the inflow of FDI while at the same time preserving the environment. Having this in mind, is it crucial to establish a stable legal structure, since regulation has an important role in this theme.

Regulation can shift attitudes, encouraging investment in R&D, and increasing RES use. Given the unexpected result that regulation shows in high-income countries, these countries must combine different policy tools to reach the goal of decreased emissions. For instance, not only regulation in the form of fees and taxes but also subsidies are recommended. The incorporation of subsidies for efficient firms with a high innovation level and, highly qualified workers, for example, could encourage investment in R&D. These subsidies must reward the investment that companies are obliged to carry out. The creation of direct subsidies for researchers and the foundation of research centers should be strongly recommended. Increasing the human capital level of countries will increase their environmental awareness. An increase in the use of RES is also required. However, given that renewable energies present higher costs than fossil fuels, policymakers should introduce policies to increase the competitiveness of RES, decreasing investment costs.

Increasing the stringency of the environmental laws of the countries under analysis is required. If their human capital level escalates, that will be reflected in more innovation and efficiency. Furthermore, middle-income countries must improve their evaluation criteria for FDI quality, and to strengthen their attractiveness for the entry of new multinational enterprises, enterprises that could transfer their advanced and eco-friendly technologies and efficient management skills. Recipient countries must absorb these technologies to change their industrial structure. Co-operation between countries has high applicability to guarantee the transference of knowledge and efficiency. It is also important to remember that corruption is a severe concern that is difficult to control. Policymakers from high-income countries must increase the stringency of outflow FDI, controlling all external headquarters of domestic firms, checking that these companies are investing in innovation and transferring their knowledge, and not avoiding environmental compliance costs and just relocating their emissions. With this co-operation and the combination of different policy tools mutually, high-income countries would be discouraged from transferring their polluting industries, and middle-income countries would not accept their entrance.

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Appendix

Table A1. Countries' groups

High-income countries		**Middle-income countries**
Austria	The Netherlands	Argentina
The Czech Republic	Norway	Bulgaria
France	Portugal	Croatia
Germany	Spain	Peru
Greece	The United Kingdom	Philippines
Hungary		Romania
Ireland		South Africa
Japan		Turkey

Table A2. Descriptive statistics

	High-income					**Middle-income**				
	Obs	**Mean**	**Std. Dev**	**Min.**	**Max.**	**Obs**	**Mean**	**Std. Dev**	**Min.**	**Max.**
LCO_2	221	2.004	0.279	1.401	2.479	136	1.173	0.712	-0.293	2.1238
LCO_2I	221	-13.815	0.388	-14.734	-13.048	136	-14.449	0.658	-16.017	-13.626
LFDI	221	-4.548	1.107	-7.835	-1.664	136	-6.415	1.044	-8.945	-4.638
LY	221	8.937	0.521	7.798	10.121	136	7.256	0.658	5.813	8.379
LTO	221	4.373	0.502	2.986	5.421	136	4.125	0.387	3.084	4.882
LEF	221	0.182	0.421	-0.693	1.344	136	-0.416	0.486	-2.159	0.331
LPAT	221	-8.737	1.150	-11.481	-5.806	136	6.006	1.203	3.296	9.009
LREG	221	0.874	0.213	0.299	1.380	136	0.483	0.809	-1.505	1.427
$DLCO_2$	208	-0.013	0.041	-0.124	0.096	128	0.012	0.055	-0.154	0.134
$DLCO_2I$	208	-0.020	0.094	-0.408	0.408	128	-0.006	0.123	-0.518	0.313
DLFDI	208	0.084	0.166	-0.371	0.718	128	0.115	0.224	-0.661	0.603
DLY	208	0.007	0.083	-0.262	0.415	128	0.0522	0.123	-0.464	0.427
DTO	208	0.015	0.066	-0.340	0.181	128	0.012	0.099	-0.295	0.647
DLTO	208	-0.020	0.094	-0.408	0.408	128	-0.006	0.123	-0.518	0.3128
DLEF	208	0.016	0.056	-0.181	0.246	128	0.020	0.173	-1.164	1.279
DLPAT	208	-0.008	0.100	-0.399	0.420	128	0.023	0.193	-0.811	0.524
DLREG	208	-0.005	0.047	-0.214	0.241	128	-0.010	0.119	-0.503	0.333

Table A3. Correlation matrices and VIF statistics (high-income - industry sector)

	LCO_2I	***LFDI***	***LY***	***LE***	***LTO***	***LPAT***	***LREG***		$DLCO_2I$	***DLFDI***	***DLY***	***DLE***	***DLTO***	***DLPAT***	***DLREG***
LCO_2I	1.000							$DLCO_2I$	1.000						
LFDI	-0.049	1.000						***DLFDI***	-0.044	1.000					
LY	0.592	0.378	1.000					***DLY***	0.264	0.230	1.000				
LE	0.224	0.472	0.690	1.000				***DLE***	-0.431	0.185	0.154	1.000			
LTO	-0.085	0.688	-0.111	0.059	1.000			***DLTO***	0.292	-0.088	0.171	0.192	1.000		
LPAT	0.498	-0.245	0.503	0.477	-0.458	1.000		***DLPAT***	-0.147	0.033	-0.143	-0.019	-0.071	1.000	
LREG	-0.151	0.322	-0.285	-0.402	0.552	-0.482	1.000	***DLREG***	-0.026	-0.083	-0.351	-0.122	-0.054	-0.025	1.000
VIF		4.71	2.68	3.77	3.04	2.48	2.21			1.12	1.28	1.10	1.09	1.03	1.15
$\mathbf{VIF_{MEAN}}$				3.15								1.13			
Cross-sectional dependence															
CD-test	22.34***	29.06***	10.21***	17.02***	25.91***	4.10***	5.49***		9.552***	16.816***	14.552***	0.487	22.29***	0.755	3.789***

Table A4. Correlation matrices and VIF statistics (middle-income - industry sector)

	LCO_2I	*LFDI*	*LY*	*LE*	*LTO*	*LPAT*	*LREG*		*$DLCO_2I$*	*DLFDI*	*DLY*	*DLE*	*DLTO*	*DLPAT*	*DLREG*
LCO_2I	1.000							***$DLCO_2I$***	1.000						
LFDI	0.523	1.000						***DLFDI***	0.217	1.000					
LY	0.665	0.793	1.000					***DLY***	0.278	0.306	1.000				
LE	-0.653	-0.214	-0.076	1.000				***DLE***	-0.092	-0.102	0.004	1.000			
LTO	-0.153	0.197	0.022	0.016	1.000			***DLTO***	0.071	-0.221	0.058	0.335	1.000		
LPAT	0.753	0.616	0.769	-0.383	0.230	1.000		***DLPAT***	0.105	-0.002	0.076	-0.009	0.056	1.000	
LREG	0.783	0.558	0.725	-0.387	0.183	0.787	1.000	***DLREG***	0.015	0.080	-0.138	0.030	0.127	-0.105	1.000
VIF		3.71	8.55	1.99	1.51	4.50	3.47			1.19	1.16	1.14	1.21	1.02	1.06
VIF_{MEAN}				3.96								1.13			
Cross-sectional dependence															
CD-test	5.057***	17.545***	15.859***	4.56***	2.413**	-2.407**	2.538**		1.886*	5.209***	6.718***	-0.261	8.943***	-1.127	2.994***

Table A5. Diagnostic tests (industry sector)

	High-income	Middle-income
Robust Hausman test	134.02***	34.59***
Wooldridge test	18.626***	31.100***
Breusch Pagan LM	106.085**	41.991**
Modified Wald test	321.73***	224.62***

Notes: *** , ** denote significance at 1%, 5% level, respectively. The null hypothesis for the Robust Hausman test is "difference in coefficients is not systematic".