Different Effect of Inward Foreign Direct Investment, Outward Foreign Direct Investment, Imports, and Exports on Greenhouse Gas Emission across 24 European Union Countries

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Abstract. The European Union (EU) has achieved remarkable progress in reducing greenhouse gas emission with the help of the emission trade system (ETS) and other environmental policies for the past decades. The main purpose of current study is to empirically investigate different effects of inward foreign direct investment, outward foreign direct investment (FDI), imports and exports on greenhouse gas (GHG) emissions for different level of GDP per capita. Panel data set of 24 European Union countries was selected from 2013 to 2017. And these 24 countries would be further divided into two groups based on their GDP per capita. The result indicates that inward FDI would decrease GHG emission for high GDP per capita group, whereas it increases the GHG emission for low GDP per capita group, suggesting the existence of "pollution haven" in countries with lower GDP per capita. On the contrary, the effect of outward FDI on GHG emission would be positive for high GDP per capita group but negative for low GDP per capita group. Meanwhile, exports would increase GHG emission for low GDP per capita group but decrease GHG emission for high GDP per capita group. Besides, imports would also be a contributor of GHG emission for high GDP per capita group. The conclusion drawn from this study implicates that, to reduce the domestic GHG emissions, countries with different level of GDP per capita should have different strategies. For countries with high level of GDP per capita, it would be more effective to attract inward FDI while for countries with low level of GDP per capita, promoting environmental policies with subsidies to encourage domestic producer to adopt newer and cleaner technology would be primary.

Keywords: Inward foreign direct investment; outward foreign direct investment; greenhouse gas emission; panel quantile regression.

1. Introduction

All For the past decades, global warming, which is mainly caused by the emission of greenhouse gases, has become a rising concern. Although the American account for the biggest part of the cumulative CO_2 emissions, for many years, countries in Europe were the major emitter [1] and most of these countries formed the European Union (EU) in 1993.

Between 1990 and 2018, the emissions in EU wide have fallen by 21% [2], while the international energy agency (IEA) states that the global energy-related CO_2 emissions have risen from 20.5 Gt in 1990 to 33.5 Gt in 2018 [3]. The reduction of the emissions could be attributed to two different reasons, one focusing on domestic aspect while the other one focusing on international aspect. For domestic aspect, by implementing more stringent environmental policies and promoting the European Union Emissions Trading Scheme (EU ETS), firms were induced to lower their emission from production, especially via investing in emission-related technology. And it is worthwhile to mention that after the pilot phase of the ETS, compared to the unregulated firms, the regulated firms are estimated to reduce 8-12% carbon dioxide emission without causing any negative impact on the scale of production [4]. For international aspect, at firm level, by replicating domestic activities or splitting activities in foreign countries with looser regulation on emissions [5], the polluting industries managed to lower their emissions in the home country, which is generally regarded as carbon leakage. Meanwhile, at country level, the developed countries could reduce their emissions by shifting to high value-added industries and assigning the highly polluting industries to the developing countries, as the cost of production and the price of the intermediate goods could be further cut down with low wage rates and tax rates in these countries,

This paper will not investigate the relationship between domestic environmental regulations, technology investment and carbon emissions, since a tremendous number of studies about these topics have been done. Instead, as fewer studies have be done about the international aspect, and most of which focus either on trade openness or inward FDI only, this study will seek for the effects of imports, exports, inward FDI, and outward FDI on greenhouse gas emissions across 24 EU countries.

For the rest of the paper, section 2 is about literature review. Section 3 would introduce methodology and data while the empirical result and robustness check would be presented in section 4. Section 5 would discuss about the data and methodology limitation. And the last section will focus on conclusion and implication.

2. Literature Review

2.1 Exports, imports and greenhouse gas emissions

For most studies focusing on the nexus between international trade and greenhouse gas emissions, three aspects are commonly considered, one focusing on imports only, another one focusing exports only, and the last one adding them together to get trade openness. For exports, the demand for export goods increases GHG emission through energy consumption in the production process from value adding to the finished goods [6]. Therefore, the increase of the total amount of exports would result in an increase of GHG emissions.

Nonetheless, from the perspective of within-industry efficiency, since larger size of the production makes the fixed cost of adopting cleaner technology bearable, firm productivity is negatively related to emission intensity with the adoption of newer and cleaner technology, especially for exporting firms, as they have the incentive to cater to the foreign market whose environmental criteria are higher [7]. Thus, higher exports could also have a negative impact on GHG emissions. But the cost of adopting cleaner technology and the profit from exports are different for different countries, hence the existence of the negative effect of higher exports on GHG emissions might depends on the position of specified country within the global value chain (GVC).

Hypothesis 1 (H1). *The net effect of exports on GHG emissions is positive.*

For imports, one opinion is that energy consumption in transportation activities would be increased with the increase of trade flow by imports [8]. Another study implied that tariff reductions would trigger increase in imports and annual earnings of domestic firms would significantly decrease with exogenous increase in competition [9]. Confronted with the competition from imports, some of the firms would choose to upgrade quality of theirs products or differentiate products [10], a few firms might swift to foreign markets, the rest of the firms would either reduce their price or quantity to meet the market demand, or quit to avoid further loss, which suggests the possibility that by taking the market share from domestic firms, imports have a negative effect on local GHG emissions. Study also showed that, the effects of imports on carbon emission for most polluted countries and less polluted countries are different [11]. Additionally, imports would increase consumption-base emissions while exports would lower them [12].

Hypothesis 2 (H2). *Imports have negative effect on GHG emission.*

For trade openness, study revealed that trade openness should be responsible for the environmental degradation in Organisation of Islamic Cooperation (OIC) countries [13]. In addition, Ozturk and Acaravci [14] have showed that, the growth of trade openness would increase carbon emission in long run. Yet, some researchers argued that for developing countries, especially newly industrialized countries, the effect of trade openness on carbon emission is significant and negative, and the reason is that with the circulation of goods and service improved by trade openness, excess capacity would be reduced, and technology transfer would be accelerated [15,16]

Regional trade agreement is usually considered as a main contributor to the increase of the overall trade openness, despite that the trade openness with non-members might be reduced [17]. With tariff reduced by signing regional trade agreement, more greenhouse gas would be emitted due to increasing trade between the trade agreement members, additionally, the intermediate input from these economies other than trade agreement members caused by the increase of the production for trade between the trade agreement , which would indirectly result in an increase of greenhouse gas emission for the rest of the world, even with the decrease of direct exports of these non-member countries [18].

Nevertheless, since this paper has already focused on the separate and independent effects of imports and exports on GHG emissions, trade openness would not be considered as an independent variable.

2.2 Inward FDI, outward FDI and greenhouse gas emissions

When There are numerous researches investigating the nexus between inward FDI and GHG emissions. Apart from direct emission produced by the firms funded by FDI, greenhouse gas could also be emitted from capital formation associated with FDI, for instance, the construction of new plant and equipment [19]. Thus, this study would be insufficient if FDI is not considered as a source of GHG emission.

For inward FDI, there are two primary but opposite hypotheses, causing a great deal of debates. One is “pollution havens”, which argues that since the environmental standards in less developed countries, especially developing and emerging countries, are usually set at a low level to attract FDI from pollution intensive industries, which are seeking for relocation due to stringent environmental policies in home countries, GHG in host economies would increase correspondingly, and the unscrupulous competition to attract FDI would further have a chilling effect on global environment standards [20]. The other one, “pollution halos”, contends that the low-carbon technology transfer associated with FDI could positively affect the GHG emission in host economies [21], and free marketers claims that better management, typically from the developed countries, diffuse with FDI and contributes to the decrease of GHG emissions in host countries [22].

Hypothesis 3a (H3a). *Inward FDI has a positive effect on GHG emission in host economies.*

Hypothesis 3b (H3b). *Inward FDI has a negative effect on GHG emission in host economies.*

Although under the hypothesis of “pollution havens”, pollution intensive industries would relocate in countries with less stringent environmental policies, which means the outward FDI should be related to the reduction of GHG emission in home countries, the investigations about the relationship between outward FDI and GHG emission are much rarer than those about inward FDI. And generally, FDI refers to inward foreign direct investment by default. Thus, the investigation about outward FDI might be illuminating in understanding the complete relationship between direct foreign investment and GHG emission across different countries.

Kayam [23] illustrated that, in developing countries, outward FDI would decrease as a response to the improvement of the economic and political conditions in the home countries. In other words, without stringent environmental policies, a part of outflow capital would have stayed in home countries and been invested in production associated with GHG emissions. Nevertheless, research showed that, in Italy, no evidence shows that outward FDI damages production in home country [24]. The possible reason for this might be that the negative effect on local suppliers who replaced by foreign suppliers is offset by the positive effect of the new demand for intermediate goods from the home country producers due to the establishment of foreign affiliate. As a result, the net effect of outward FDI on GHG emissions is still unclear.

Hypothesis 4 (H4). *Outward FDI has statistically significant effect on GHG emission in home countries.*

Like the debate around the “Pollution haven” hypothesis and the “Pollution halos”, the environmental Kuznets curve (EKC), a hypothesis about the inverted U-shaped relationship between economic output per capita and environmental quality, also caused a great deal of arguments. A survey of OECD [25] demonstrated that FDI has positive influence on income growth in host economies. And Baek [26] stated that income has detrimental effect on carbon emissions. Therefore, it is possible for FDI to decrease GHG emissions by increasing the income level in host economies.

However, although evidence shows that EKC also holds in South Asia, ten newly industrialized countries (NICs-10) and BRICS economies [16, 27, 28], study by Dogan and Turkekul [29] did not confirm the validity of EKC for the USA. Additionally, EKC is also invalid for China [30] Moreover, EKC might have two shortages, one is it does not consider the distribution aspect, the other one is for different countries, the time scales with respect to long run and short run are different and the positions they are in the curve are different, which means if a group of countries rather than a single country is tested for the existence of EKC in a relatively short run, the result might be unreliable. Thus, the hypothesis that FDI reduce GHG emissions by increasing the income level in host economies is quite hard to confirm.

Besides, multinational firms of different home countries tend to have different production allocation strategy. For instance, U.S. firms prefer allocating labor-intensive parts of production to affiliates in low-wage countries while Swedish firms are inclined to allocate capital-intensive parts of production to developed countries [31]. For the former one, labor-intensive parts of production are usually associated with high GHG emissions, whereas the link between capital-intensive parts of production and GHG emissions might be quite weak. Thus, the effect of the outward FDI associated with these allocations on GHG emissions could be ambiguous and varies from country to country.

Hypothesis 5a (H5a). *Whether the effect of inward FDI on GHG emission is positive or* ***negative*** *depends on GDP per capita of the country.*

Hypothesis 5b (H5b). *Whether the effect of outward FDI on GHG emission is positive or negative depends on GDP per capita of the country.*

2.3 Carbon leakage

Carbon leakage could be defined as changes in economic activities and investment pattern which directly or indirectly result in a shift of GHG emissions from countries with stringent pollution constrains to countries with looser environmental policies [32]. Under this definition, imports, inward FDI and outward FDI could be regarded as being involved in carbon leakage. However, Sato and Burke [33] revealed the general confusion over the use of this terminology and emphasized that carbon leakage should be specified to the emissions offshoring resulted from the international climate policy asymmetries. From the theoretical perspective, a decrease of GHG in some countries, especially developed countries, which is associated with an increase of GHG in the other countries, usually developing countries, could be interpreted in three ways. The first way to be considered is the typical carbon leakage, which is about how firms transfer their productivity to jurisdictions with laxer constraint on pollution to avoid the emissions regulation in home countries. Another one considering the case in which an increase of private disposable income associated with an increase of ratio of consumption to production would probably result in an increase of ratio of imports to exports, and in the end home country is led to trade-embodied carbon deficit. The last one focuses on the industrial upgrading, which implies that the high value-added industries developed and controlled by most developed countries, as with finance and services, usually combine the advantage of high profit and low pollution, while the labour-intensive industries hosted mostly in developing countries are of less profit and might even be highly polluting. Besides, a decrease in the ratio of goods to services with respect to the national economy activities would have the similar effect since demands for goods undertook by foreign would increase correspondingly. Practically, this paper would not distinguish the differences between these ways as it requires firm-level data.

2.4 Other factors influencing greenhouse gas emission

Prior research revealed that energy consumption would positively affect GHG emission [34], whereas another investigation showed a slight influence of financial development on carbon emissions [35]. Meanwhile, Abbas, et al., [36] argued that fixed capital formation had negative influence on carbon emission over time. And the long run effect of density of population on GHG emission was also stated to be positive[37]. Therefore, all of them should be considered as control variables.

Although technology innovation plays a momentous role in environmental issues [39], it is hard to properly evaluate the progress has been made in green technology. Because it would cause bias to simply measure technology innovation using the total number of patents application, and it is too difficult to get the exact number of patents associated with green technology. Therefore, it would not be used as control variable.

3. Methodology and Data

3.1 Econometric model

The baseline model is developed by Chen et al. [40], shown as follows:

$$CO2emissions_{it} = \alpha_0 + \alpha_1 tradeopenness_{it} + \sum_{j=1}^{k} \beta_j CV_{j,it} + \varepsilon_{it}. \quad (1)$$

Where trade openness, the independent variable, is measured by the total sum of import and export for goods, and carbon emissions, the dependent variable, is measured by per capita CO2 emissions. CVj is the control variable j, including capital formation, consumption of fossil fuel, financial development, population, research and development, energy price, urbanization, household expenditure, and FDI inlows. The control variables were set for avoiding the bias of variables omission.

The moderated regression is specified as follows:

$$GHG\_PC = \alpha_0 + \alpha_1 IFDI + \alpha_2 OFDI + \alpha_3 IP + \alpha_4 EP + \sum_{j=1}^{k} \beta_j CV_j + \varepsilon \quad (2)$$

The dependent variable would be greenhouse gas emissions measured by per capita GHG emissions instead of carbon emissions and the independent variables would be replaced by inward FDI, outward FDI, imports and exports, measured by percent to GDP, respectively. Besides, density of population, financial development level, fossil fuel energy consumption and gross fixed capital formation are retained as control variables.

The reason for choosing greenhouse gas emissions instead of carbon emission as the subject of the investigation is, despite most of the previous studies about emission focus on carbon emissions, it would be more precise to capture the effect of human activities on global warming using greenhouse gas emissions instead of carbon emissions.

Table 1. Details of variable.

Variable	Symbol	Meaning	Measurement
Dependent variable	GHG_PC	Greenhouse gas emission per capita	Tonnes per capital
Independent variables	IFDI	Inward foreign direct investment	(stock in % of GDP)
	OFDI	Outward foreign direct investment	(stock in % of GDP)
	IP	Import of goods and services	(% of GDP)
	EP	Export of goods and services	(% of GDP)
Control variables	DOL	Density of population	Population per kilometre of land area
	FDL	Financial development level	Domestic private sector credit (% of GDP)
	FFCL	Fossil fuel energy consumption	Share of fossil fuels in gross available energy
	GFCF	Gross fixed capital formation	chain linked volumes (index 2005 = 100)

Note: data are drawn from European statistics (eurostat) and the World Development Indicators of World Bank Database (WDI)

Greenhouse gases (CO2, N2O in CO2 equivalent, CH4 in CO2 equivalent, HFC in CO2 equivalent, PFC in CO2 equivalent, SF6 in CO2 equivalent, NF3 in CO2 equivalent).

3.2 Data description

The panel data of this study is drawn from WDI and Eurostat for 28 European Union (EU) countries from 2013 to 2017 (details shown in table 2). Cyprus, Luxembourg, Malta and Netherland are excluded in this study because their average FDI are between 300% to 5000% of the GDP, which means the relationship between FDI and domestic production associated with GHG emission is quite weak, hence they are not valuable for this study.

Table 2. List of European Union members (before Brexit).

Austria	Belgium	Bulgaria	Croatia	Cyprus	Czechia	Denmark
Estonia	Finland	France	Germany	Greece	Hungary	Ireland
Italy	Latvia	Lithuania	Luxembourg	Malta	Netherland	Poland
Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom

Table 3 shows the result of descriptive statistic. Inward FDI, outward FDI, exports and imports respectively account for 63.149%, 46.851%, 57.259% and 54.128% of GDP on average, which means that most EU countries heavily participated into international trade. The standard deviation for inward FDI and outward FDI are 51.680 and 59.114, indicating that EU countries have high difference in investing activity associated with foreign countries, while the standard deviation for exports and imports are 23.291 and 20.396, relatively low compared to FDI. Plus, the minimum value of inward FDI is 9.9 while maximum value is 311.5, which represents that inward FDI takes a small part of economy in some countries yet contributes a lot in some other countries. Similarly, for outward FDI, the minimum value of 0.2 implies in some countries, outward FDI is either restricted or underdeveloped, and the maximum value of 318.3 might be associated with highly developed finance. Additionally, the maximum value of exports is 122.1, suggesting that some EU countries are export-oriented, and the maximum value of imports is 106, which is more than 100, too, showing that some EU countries are importing goods and services which exceed their GDP. Besides, for per capita GHG emissions, standard deviation is 3.127, suggesting among EU countries, per capita emissions of GHG are quite similar.

Table 3. Descriptive statistics of variables.

	Average	Median	Standard Deviation	Min	Max
IFDI	63.149	53.35	51.680	9.9	311.5
OFDI	46.851	27	59.114	0.2	318.3
EP	57.259	52.75	23.291	27.3	122.1
IP	54.128	48.05	20.396	26	106
DOP	113.811	102.75	81.160	17.9	373.7
FFEC	71.681	73.19	13.799	30.29	17.9
GFCG	107.743	107.611	29.630	47.093	199.601
FDL	79.772	68.81245	36.221	26.47339	177.0154
GHG_PC	7.925	7.35	3.127	1.6	15.3

3.3 Unit root test

To make sure that time series is not biased by non-stationarity, the Augmented Dicky-Fuller (ADF) Test is done. The null hypothesis of ADF test is the existence of unit root, which indicates the time series are non-stationary. And the result shows that inward FDI, outward FDI, density of people, gross fixed capital formation and financial development level are stationary. Besides, at first difference, imports, exports and fossil fuel energy consumption are stationary, too. Thus, the requirement for cointegration test is satisfied.

Table 4. ADF test (Augmented Dicky-Fuller Test).

Variable	At level	At 1st difference
IFDI	3.875***(0.002)	
OFDI	3.762***(0.003)	
IP	-2.436(0.132)	-5.951***(0)
EP	-2.408(0.14)	-5.901***(0)
DOP	-3.055**(0.03)	
FFEC	-2.488(0.118)	
GFCF	-5.248***(0)	-5.757***(0)
FDL	3.635***(0.005)	

Notes: p-value are in parenthesis, *, **, ***, represents significance level of 1%, 5%, and 10%l, respectively, critical value for 1%, 5%, 10% are -3.487, -2.886 and -2.58 respectively

3.4 Cointegration test

Spurious regression is about a major concern that variables are associated but without causality. To avoid spurious regression caused by a lack of cointegration between non-stationary time series, this study examines the cointegration by Johansen cointegration test. And the result implies that, at the significance level of 10%, the null hypothesis of 8 cointegrations at most is rejected, suggesting a long run relationship among all variables in the selected countries in EU under this study (shown in table 5).

Table 5. Johansen cointegration test (Trace).

Null hypothesis H0	eigenvalue	Max-Eigen	10% critical value	5% critical value	1% critical value
None (no cointegration)	0.845	176.858	55.241	58.433	64.996
At most 1	0.627	93.674	49.285	52.362	58.663
At most 2	0.474	60.959	43.295	46.23	52.307
At most 3	0.288	32.244	37.279	40.076	45.866
At most 4	0.197	20.812	31.238	33.878	39.369
At most 5	0.184	19.316	25.124	27.586	32.717
At most 6	0.181	18.913	18.893	21.131	25.865
At most 7	0.111	11.18	12.297	14.264	18.52
At most 6	0.086	8.546	2.705	3.841	6.635

3.5 Heteroscedasticity test

It is also necessary to test heteroscedasticity since homoscedasticity is one of the ordinary least squares assumptions. And both White test and BP test reject the null hypothesis of homoscedasticity, indicating that robust standard errors should be considered in following regression sections.

Table 6. Heteroscedasticity test result.

White test		*BP* test	
χ^2	p	χ^2	p
105.133	0	31.119	0

3.6 Hausman test

Hausman test is done to choose between random effect model and fixed effect model. And the p-value is greater than 0.05, indicating that random effect model fits better in this study.

Table 7. Result of the Hausman Test

test summary	Chi-Sq. Statistics	*p-value*
Hausman Test	2.255	0.972

4. Empirical result

4.1 Random effect model

All 24 selected EU countries are included in the random effect model with robust standard error, and the result is reported in table 8. P values indicates that inward FDI, imports and exports have statistically significant effects on GHG emission. But the null hypothesis for outward FDI cannot be rejected. Thus, H4 cannot be confirmed. The coefficient of IFDI is -0.016, which suggests a small and negative effect on GHG emission, consistent with H3b. Similarly, for imports, the coefficient is -0.083, implying a small and negative effect on GHG emission, which is consistent with H2, while for exports, the coefficient is 0.11, indicating a relatively large and positive effect on GHG emission, which supports H1.

Table 8. Result of random effect model with robust standard error.

variable	Coeff	Std. Err	*t*	*p*	95% CI
Intercept	-5.425	2.603	-2.084	0.039*	-10.527 ~ -0.324
IFDI	-0.016	0.006	-2.534	0.013*	-0.029 ~ -0.004
OFDI	0.009	0.007	1.224	0.224	-0.005 ~ 0.023
EP	0.110	0.035	3.102	0.002**	0.040 ~ 0.179
IP	-0.083	0.033	-2.511	0.013*	-0.148 ~ -0.018
DOP	-0.002	0.007	-0.269	0.788	-0.015 ~ 0.012
FFEC	0.158	0.036	4.345	0.000**	0.087 ~ 0.229
GFCF	0.013	0.006	2.019	0.046*	0.000 ~ 0.025
FDL	-0.004	0.011	-0.394	0.694	-0.025 ~ 0.017

$\chi^2(8)$ =94.884, p =0.000
R^2=0.532, R^2(within)=0.308
* p<0.05 ** p<0.01

Regarding inward FDI, the quantile coefficients are negative and statistically significant, except at the 10th and 20th quantile levels, which support H3b, consistent with the result from random effect model. However, the effect of outward FDI on GHG emissions is statistically positive, except at the 10th and 20th quantile levels, which support H4, different from the conclusion drawn from random effect model. And positive effect of exports on GHG emissions is only statistically significant at 10th, 20th, 30th and 50th quantile level, implying that exports would positively affect GHG emission at low quantile level while have no effect on GHG emission at high quantile level, which partly support H1. Whereas for import, the coefficient is statistically significant at 20th quantile levels, although this result cannot effectively confirm H2, it is consistent with the discussion in imports part which suggest the effect of import on GHG emissions is quite complicate and ambiguous with the trade of intermediate goods.

Furthermore, to test hypothesis 5a and 5b, the total sample is divided into two subsamples according to GDP per capita, the low GDP per capita group has 12 countries, including Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Portugal, Romania and Slovakia, with GDP per capita lower than 20000 euro (result shown in table 10), while the high GDP per capita group has 12 countries, including Austria, Belgium, Denmark. Finland, France, Germany, Ireland, Italy, Slovenia, Spain, Sweden and United Kingdom (result shown in table 9).

Table 9. Panel quantile regression result for high GDP per capita group.

variable	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC
quantiles	10th	20th	30th	40th	50th	60th	70th	80th	90th
constant	-14.533**	-14.008**	-12.965**	-10.094**	-7.314**	-7.228**	-8.882**	-4.319	-7.711**
	(-6.019)	(-5.400)	(-5.720)	(-4.879)	(-3.513)	(-3.725)	(-4.692)	(-1.919)	(-3.054)
IFDI	-0.076**	-0.068**	-0.077**	-0.089**	-0.070**	-0.079**	-0.084**	-0.056**	-0.064**
	(-4.710)	(-4.267)	(-5.342)	(-6.485)	(-4.894)	(-5.989)	(-5.960)	(-3.836)	(-3.420)
OFDI	0.036*	0.033*	0.040**	0.059**	0.051**	0.060**	0.061**	0.048**	0.054**
	(2.173)	(2.047)	(2.954)	(4.743)	(4.114)	(5.372)	(5.561)	(4.738)	(4.848)
EP	-0.091	-0.165*	-0.221**	-0.172**	-0.047	-0.119	-0.196**	-0.029	-0.136
	(-1.393)	(-2.418)	(-3.375)	(-2.696)	(-0.707)	(-1.916)	(-2.795)	(-0.370)	(-1.367)
IP	0.223**	0.303**	0.365**	0.292**	0.135	0.213**	0.305**	0.096	0.240*
	(2.813)	(3.6)	(4.674)	(3.913)	(1.779)	(2.978)	(3.781)	(1.059)	(2.032)
DOP	-0.010*	-0.012**	-0.013**	-0.012**	-0.008*	-0.012**	-0.015**	-0.010**	-0.011*
	(-2.596)	(-3.075)	(-3.628)	(-3.599)	(-2.195)	(-3.696)	(-4.527)	(-2.777)	(-2.527)
FFEC	0.207**	0.212**	0.202**	0.199**	0.161**	0.169**	0.195**	0.140**	0.165**
	(7.536)	(7.496)	(7.716)	(8.446)	(7.282)	(8.837)	(10.401)	(6.793)	(6.716)
GFCF	0.049**	0.040**	0.044**	0.033**	0.030**	0.036**	0.039**	0.032**	0.044**
	(4.917)	(3.78)	(4.563)	(3.48)	(3.06)	(3.838)	(4.14)	(3.756)	(3.919)
FDL	0.001	0.004	0.001	-0.008	-0.006	-0.01	-0.01	-0.01	-0.013
	(0.22)	(0.576)	(0.113)	(-1.285)	(-0.940)	(-1.604)	(-1.564)	(-1.241)	(-1.512)
obs	60	60	60	60	60	60	60	60	60
R^2	0.728	0.665	0.635	0.639	0.639	0.661	0.679	0.692	0.758

* p<0.05 ** p<0.01 t statistic in parenthesis

Table 10. Panel quantile regression result for low GDP per capita group.

variable	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC
quantiles	10th	20th	30th	40th	50th	60th	70th	80th	90th
constant	-23.587**	-21.925**	-20.197**	-19.679**	-19.274**	-18.997**	-17.288**	-19.318**	-25.293**
	(-6.979)	(-10.290)	(-11.725)	(-14.556)	(-12.523)	(-9.198)	(-6.665)	(-8.705)	(-8.578)
IFDI	0.045*	0.030**	0.023**	0.021**	0.017*	0.017	0.030**	0.034**	0.062**
	(2.449)	(3.135)	(2.892)	(3.272)	(2.511)	(1.974)	(2.866)	(3.119)	(3.664)
OFDI	-0.048**	-0.030**	-0.032**	-0.029**	-0.028**	-0.037**	-0.059**	-0.063**	-0.086**
	(-2.757)	(-3.632)	(-4.382)	(-4.944)	(-4.195)	(-4.180)	(-5.442)	(-5.526)	(-4.864)
EP	0.205	0.127	0.184*	0.188**	0.183*	0.246*	0.254	0.175	0.139
	(1.236)	(1.63)	(2.47)	(3.03)	(2.67)	(2.55)	(1.99)	(1.413)	(0.703)
IP	-0.14	-0.057	-0.103	-0.113	-0.107	-0.163	-0.171	-0.074	-0.029
	(-0.768)	(-0.665)	(-1.240)	(-1.663)	(-1.414)	(-1.546)	(-1.243)	(-0.564)	(-0.138)
DOP	-0.008	-0.014**	-0.013**	-0.014**	-0.012*	-0.003	0.004	0.01	-0.002
	(-0.833)	(-2.979)	(-3.032)	(-3.608)	(-2.656)	(-0.480)	(0.39)	(0.973)	(-0.139)
FFEC	0.374**	0.337**	0.317**	0.313**	0.322**	0.333**	0.339**	0.343**	0.405**
	(9.07)	(13.8)	(16.5)	(20.8)	(18.6)	(13.7)	(10.5)	(10.646)	(8.225)
GFCF	-0.033*	-0.016*	-0.019**	-0.014**	-0.020**	-0.031**	-0.046**	-0.045**	-0.041
	(-2.658)	(-2.364)	(-3.128)	(-2.696)	(-3.179)	(-3.412)	(-3.746)	(-3.419)	(-1.981)
FDL	-0.001	0.01	0.009	0.007	0	-0.011	-0.027	-0.022	-0.014
	(-0.046)	(0.87)	(0.98)	(1.03)	(0.03)	(-0.898)	(-1.683)	(-1.287)	(-0.511)
obs	60	60	60	60	60	60	60	60	60
R 2	0.586	0.643	0.681	0.698	0.706	0.714	0.728	0.742	0.743

* p<0.05 ** p<0.01 t statistic in parenthesis

Consistent with H5a, inward FDI have negative effect on GHG emission for high GDP per capita group, statistically significant at all the selected quantile levels, while effect on GHG emission for low GDP per capita group would be positive, statistically significant except at the 60th quantile level. Similarly, outward FDI have positive effect on GHG emission for high GDP per capita group, statistically significant at all quantile levels, while effect on GHG emissions for low GDP per capita group is negative and statistically significant.

The possible explanation is inward FDI for low GDP per capita group is likely be associated with firms seeking for relocation in countries with less stringent environmental policies, consistent with the “pollution haven” hypothesis. Whereas for high GDP per capita group, compared with low GDP per capita group, inward FDI is more likely to associated with high-tech industries and contributes to research and development of cleaner technology. Therefore, the effect of inward FDI on GHG emissions would be negative for high GDP per capita group. As for outward FDI, for low GDP per capita group, domestic market saturation is relatively low, which suggests part of outward FDI could have increased GHG emission through domestic production if it has not been invest to foreign countries, while for high GDP per capita group, the outward FDI is usually associated with establishment of affiliate, which would increase GHG emission through the increasing demand for intermediate goods in home country.

Regarding exports, the effect of exports on GHG emissions for high GDP per capita group is statistically significant and negative at the 20th, 30th, 40th and 70th quantile levels, and for low GDP per capita group, the effect is statistically significant and positive at 30th, 40th, 50th and 60th quantile levels, suggesting that exports are most likely to be associated with GHG emission at median and low quantile level. The possible explanation for the difference between high GDP per capita group and low GDP per capita group is, as discussed in section 2.1., the relatively cost of adopting cleaner technology for emissions intensive industries are different. For high GDP per capita group, access to cleaner technology is relatively cheaper, therefore, the scale effect of increase in exports would make adoption of cleaner technology more affordable. While for low GDP per capita group, increase of exports might be more likely to associated with increased total amount of exports and less likely to associated with adopting newer and cleaner technology since they are relatively unaffordable, which suggests a positive effect of exports on GHG emissions. Besides, it is also possible the relatively stringent environmental policies in countries with higher GDP per capita incentivized export firms to adopt cleaner technology with the increase in exports, while in countries with lower GDP per capita, the relatively loose environmental regulations might result in a lack of incentive to adopt cleaner technology even with increased profit from exports, which is partly consistent with EKC.

For imports, the effect of imports on GHG emissions for high GDP per capita group is positive and statistically significant at all quantile levels except 50th and 80th, whereas for low GDP per capita group, the effect would be insignificant at all quantile levels. The possible explanation is that, for low GDP per capita group, the positive effect from the increase of consumption-based emission is offset by the decrease of domestic production due to rising competition. But for high GDP per capita group, consumption-based emission is significantly increased by imports, and firms holding more reserves would be capable of either upgrading or differentiating their product, confronted with competition from imports. Therefore, the increase of consumption-based by imports cannot be offset.

Overall, similar with inward FDI and outward FDI, exports and imports have different effects on countries according to their GDP per capita.

4.2 Robustness check

For testing the robustness of the random effect model, a random effect model would be done with the promotion of zero emission vehicle taken as a control variable, measured by the share in newly registered passenger cars, given that road vehicle emission is still considered as a large contributor to air pollution and developing zero emissions vehicles is regarded as a corresponding solution [42]. The data for the new control variable was also obtained from Eurostat and the result is in line with the original random effect model (shown in table 11).

Table 11. Result of random effect model with robust standard error (with zero emission vehicle taken as control variable).

variable	Coeff	Std. Err	*t*	*p*	95% CI
Intercept	-5.271	2.477	-2.128	0.036*	-10.125 ~ -0.416
IFDI	-0.014	0.007	-1.998	0.048*	-0.028 ~ -0.000
OFDI	0.008	0.008	1.039	0.301	-0.007 ~ 0.023
EP	0.101	0.036	2.818	0.006**	0.031 ~ 0.171
IP	-0.078	0.034	-2.331	0.022*	-0.144 ~ -0.012
DOP	-0.002	0.007	-0.286	0.775	-0.016 ~ 0.012
FFEC	0.159	0.034	4.689	0.000**	0.092 ~ 0.225
GFCF	0.011	0.007	1.621	0.108	-0.002 ~ 0.024
FDL	-0.003	0.01	-0.342	0.733	-0.023 ~ 0.016
Vehicle	0.32	0.273	1.171	0.244	-0.215 ~ 0.856

$\chi^2(9)$ =98.189, p=0.000
R^2=0.548, R^2(within)=0.331
* p<0.05 ** p<0.01

As for the robustness of the quantile regressions, similar method is applied by considering zero emission vehicle as a control variable (shown in table 12), and the result is also mostly in line with the original quantile regression.

Table 12. Panel quantile regression for all countries (with zero emission vehicle considered as control variable).

variable	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC
quantiles	10th	20th	30th	40th	50th	60th	70th	80th	90th
constant	-9.882** (-6.304)	-9.530** (-5.143)	-9.208** (-5.364)	-10.230** (-6.056)	-8.624** (-5.282)	-9.489** (-4.917)	-4.059 (-1.639)	-9.306** (-3.860)	-8.766** (-3.963)
IFDI	-0.021 (-1.824)	-0.021 (-1.632)	-0.040** (-3.552)	-0.048** (-4.643)	-0.052** (-5.566)	-0.038** (-3.500)	-0.037** (-2.705)	-0.057** (-4.220)	-0.060** (-5.232)
OFDI	0.018* (2.51)	0.016 (1.616)	0.037** (4.024)	0.039** (4.523)	0.038** (4.696)	0.024* (2.467)	0.025 (1.964)	0.030* (2.352)	0.035** (3.378)
EP	0.190** (3.22)	0.188** (3.958)	0.017 (0.341)	0.086 (1.65)	0.136* (2.527)	0.113 (1.676)	0.104 (1.189)	0.113 (1.234)	0.029 (0.329)
IP	-0.142* (-1.995)	-0.139* (-2.400)	0.054 (0.947)	-0.017 (-0.289)	-0.061 (-1.006)	-0.017 (-0.232)	-0.038 (-0.385)	0.028 (0.273)	0.114 (1.137)
DOP	0.004 (1.962)	0.005 (1.727)	0 (-0.089)	-0.002 (-0.715)	0 (0.129)	0 (0.05)	-0.001 (-0.350)	-0.007 (-1.569)	-0.008 (-1.939)
FFEC	0.139** (10.756)	0.143** (10.045)	0.164** (11.065)	0.182** (11.974)	0.169** (11.453)	0.162** (9.149)	0.128** (5.858)	0.112** (5.003)	0.115** (5.725)
GFCF	0.011 (1.89)	0.007 (0.98)	-0.002 (-0.329)	0.007 (1.048)	0.004 (0.58)	0.003 (0.487)	0.008 (1.085)	0.032** (5.779)	0.044** (9.347)
FDL	0.020* (2.588)	0.017 (1.841)	0.012 (1.387)	0.008 (1.004)	0.003 (0.371)	0.011 (1.456)	-0.002 (-0.206)	0.030** (3.814)	0.017* (2.4)
Vehicle	0.188 (0.299)	1.206* (2.179)	1.784** (3.222)	1.698** (3.23)	1.601** (3.25)	1.361* (2.407)	1.431 (1.981)	0.673 (0.901)	0.417 (0.479)
obs	120	120	120	120	120	120	120	120	120
R^2	0.547	0.515	0.481	0.465	0.465	0.447	0.434	0.47	0.549

* p<0.05 ** p<0.01 t statistic in parenthesis

Additionally, when it comes to panel quantile regression for high GDP per capita group and low GDP per capita group, with same method of taking zero emission vehicle as control variable, the results are also mostly consistent with original regressions (shown in table 13, table 14 respectively).

Table 13. Panel quantile regression for high GDP per capita group (with zero emission vehicle taken as control variable).

variable	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC
quantiles	10th	20th	30th	40th	50th	60th	70th	80th	90th
constant	-9.882**	-9.530**	-9.208**	-10.230**	-8.624**	-9.489**	-4.059	-9.306**	-8.766**
	(-6.304)	(-5.143)	(-5.364)	(-6.056)	(-5.282)	(-4.917)	(-1.639)	(-3.860)	(-3.963)
IFDI	-0.021	-0.021	-0.040**	-0.048**	-0.052**	-0.038**	-0.037**	-0.057**	-0.060**
	(-1.824)	(-1.632)	(-3.552)	(-4.643)	(-5.566)	(-3.500)	(-2.705)	(-4.220)	(-5.232)
OFDI	0.018*	0.016	0.037**	0.039**	0.038**	0.024*	0.025	0.030*	0.035**
	(2.51)	(1.616)	(4.024)	(4.523)	(4.696)	(2.467)	(1.964)	(2.352)	(3.378)
EP	0.190**	0.188**	0.017	0.086	0.136*	0.113	0.104	0.113	0.029
	(3.22)	(3.958)	(0.341)	(1.65)	(2.527)	(1.676)	(1.189)	(1.234)	(0.329)
IP	-0.142*	-0.139*	0.054	-0.017	-0.061	-0.017	-0.038	0.028	0.114
	(-1.995)	(-2.400)	(0.947)	(-0.289)	(-1.006)	(-0.232)	(-0.385)	(0.273)	(1.137)
DOP	0.004	0.005	0	-0.002	0	0	-0.001	-0.007	-0.008
	(1.962)	(1.727)	(-0.089)	(-0.715)	(0.129)	(0.05)	(-0.350)	(-1.569)	(-1.939)
FFEC	0.139**	0.143**	0.164**	0.182**	0.169**	0.162**	0.128**	0.112**	0.115**
	(10.756)	(10.045)	(11.065)	(11.974)	(11.453)	(9.149)	(5.858)	(5.003)	(5.725)
GFCF	0.011	0.007	-0.002	0.007	0.004	0.003	0.008	0.032**	0.044**
	(1.89)	(0.98)	(-0.329)	(1.048)	(0.58)	(0.487)	(1.085)	(5.779)	(9.347)
FDL	0.020*	0.017	0.012	0.008	0.003	0.011	-0.002	0.030**	0.017*
	(2.588)	(1.841)	(1.387)	(1.004)	(0.371)	(1.456)	(-0.206)	(3.814)	(2.4)
Vehicle	0.188	1.206*	1.784**	1.698**	1.601**	1.361*	1.431	0.673	0.417
	(0.299)	(2.179)	(3.222)	(3.23)	(3.25)	(2.407)	(1.981)	(0.901)	(0.479)
obs	120	120	120	120	120	120	120	120	120
R^2	0.547	0.515	0.481	0.465	0.465	0.447	0.434	0.47	0.549

* p<0.05 ** p<0.01 t statistic in parenthesis

Table 14. Panel quantile regression for low GDP per capita group (with zero emission vehicle taken as control variable).

variable	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC	GHG_PC
quantiles	10th	20th	30th	40th	50th	60th	70th	80th	90th
constant	-20.961**	-21.583**	-19.899**	-20.209**	-18.770**	-18.494**	-16.943**	-17.999**	-22.438**
	(-7.454)	(-11.676)	(-13.026)	(-12.636)	(-12.781)	(-9.356)	(-7.726)	(-6.796)	(-9.992)
IFDI	0.046**	0.028**	0.023**	0.023**	0.018**	0.014	0.025*	0.039**	0.061**
	(3.039)	(2.954)	(2.875)	(3.219)	(2.767)	(1.75)	(2.527)	(3.153)	(6.371)
OFDI	-0.048**	-0.034**	-0.032**	-0.034**	-0.028**	-0.035**	-0.055**	-0.069**	-0.089**
	(-3.610)	(-4.097)	(-4.568)	(-4.999)	(-4.447)	(-4.107)	(-5.360)	(-5.452)	(-6.506)
EP	0.191	0.069	0.149*	0.183*	0.182**	0.232*	0.258*	0.175	0.264
	(1.707)	(0.891)	(2.194)	(2.636)	(2.791)	(2.491)	(2.135)	(1.096)	(1.364)
IP	-0.141	0.013	-0.068	-0.106	-0.11	-0.149	-0.177	-0.084	-0.178
	(-1.185)	(0.15)	(-0.917)	(-1.382)	(-1.534)	(-1.465)	(-1.370)	(-0.492)	(-0.861)
DOP	-0.006	0	-0.008	-0.007	-0.011*	-0.001	0.006	0.009	-0.007
	(-0.811)	(0.046)	(-1.862)	(-1.649)	(-2.484)	(-0.190)	(0.626)	(0.767)	(-0.507)
FFEC	0.327**	0.338**	0.321**	0.326**	0.312**	0.325**	0.338**	0.339**	0.390**
	(8.745)	(14.238)	(17.298)	(18.193)	(18.904)	(14.129)	(12.042)	(9.226)	(10.424)
GFCF	-0.02	-0.028**	-0.024**	-0.021**	-0.019**	-0.031**	-0.046**	-0.049**	-0.040*
	(-1.964)	(-3.795)	(-3.819)	(-3.620)	(-3.176)	(-3.479)	(-3.935)	(-3.214)	(-2.230)
FDL	0.001	-0.005	-0.001	-0.001	0.004	-0.01	-0.029	-0.027	-0.016
	(-0.055)	(-0.448)	(-0.088)	(-0.143)	(0.459)	(-0.905)	(-1.950)	(-1.326)	(-0.611)
Vehicle	0.956	0.823	0.631	0.472	0.51	0.6	0.579	1.379	1.396
	(0.962)	(1.605)	(1.555)	(1.317)	(1.54)	(1.22)	(0.919)	(1.564)	(1.134)
obs	60	60	60	60	60	60	60	60	60
R^2	0.62	0.663	0.695	0.708	0.714	0.724	0.734	0.756	0.776

* $p<0.05$ ** $p<0.01$ t statistic in parenthesis

5. Data and Methodological Limitation

Exports and imports are commonly measured at current price, though in practice it is the most realistic way of measurement, this measure method is rather imprecise, as the relationships between price and carbon embodied with respect to raw material, intermediate good and final product are different, and distribution of upstream industries and downstream industries is uneven at nation level. due to a lack of industry level data, the main channel through which imports and exports affect GHG emissions is still unclear. Thus, it would be better if the data of imports and exports for goods could be further specified raw material intermediate goods or final products

Besides, only 5 years data are available in Eurostat before Brexit, considering all variables used in this study. Further study of including the following 5 years from 2018 to 2022 would be far more challenging, as pandemic after 2020 caused a global shock on both imports and exports. Apart from that, the impact from Brexit to EU emission trading system (ETS) is tremendous too, since British withdrew and decided to set up its own ETS, while imports and exports are also affected profoundly [41], which would increase the unfavourable disturbances for this study.

6. Conclusion and Implication

This study investigated the effects of inward foreign investment, outward foreign investment, imports and exports on the greenhouse gas emissions in European Union countries, including United Kingdom but excluding Cyprus, Luxembourg, Malta, and Netherland. Panel random effect model and quantile regression are used taking the period 2013-2017. The results imply that the effect of independent variables on GHG emissions vary for different quantile level. And for countries with GDP per capita lower than 20000 euro, inward FDI would increase GHG emissions, which supports the hypothesis of “pollution haven”, while outward FDI would have negative effect on GHG emissions. On the contrary, for countries with higher GDP per capita inward FDI would reduce GHG emissions while outward FDI would increase GHG emissions, suggesting the different structures of foreign direct investment sharped by the different level of GDP per capita would have opposite effect on GHG emissions. Moreover, the impact of exports on GHG emissions for countries with higher GDP per capita is negative, despite it is positive for countries with lower GDP per capita, which is possibly caused by the unequal costs for adopting cleaner technology and distinct environmental policies.

Besides, imports would increase GHG emissions for countries with higher GDP per capita, possibly through the increase of consumption-based emissions, while for countries with lower GDP per capita, the positive effect might be offset by the shutdown of domestic production due to rising competition and lack of reserves for upgrading or differentiating. Lastly, the effect of fossil fuel energy consumption on GHG emissions is significantly positive all the time, suggesting that replacing fossil fuel energy with cleaner energy would still be a common solution to reduce the GHG emissions.

The first implication is that due to verification of “pollution haven” and carbon leakage, the assessment of the decline of GHG emission achieved by EU should be more cautious. The second implication is that countries with higher GDP per capita should keep attract inward FDI, since it has negative effect on GHG emissions. Last, to reduce domestic GHG emission, countries with lower GDP per capita, especially the export-oriented ones, should promote policies incentivizing domestic producers to adopt newer and greener technologies with subsidies.

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