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The effect of trade openness on CO_2 emissions

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Abstract

During the last decades, both trade and carbon dioxide (CO_2) emissions have increased greatly. The plausible correlation between them is, therefore, an important question. The purpose of this thesis was to analyse the effect of trade openness on CO_2 emissions. Using a panel data regression, 161 countries were compared over a ten year period. The model used for the regression was the fixed effects model. The effect of trade openness for different income levels was also examined and analysed. The results from the regression showed that trade openness had a positive effect on CO_2 emissions, which is in line with some previous studies. It was also concluded that the effect differed between different income levels. For high-income countries, trade openness had a negative effect on CO_2 emissions. For low-income countries, the effect was the opposite. The results were interpreted and compared to previous studies. Since the regression showed that trade openness had a negative effect for high-income countries and a positive effect for low-income countries, these results are in line with the Pollution Haven hypothesis. Evidence for the Environmental Kuznets Curve (EKC) was found by observing an inverted U-shape relationship between Gross Domestic Product (GDP) and CO_2 emissions. As long as trade is an important part of the economy, greater efforts are needed globally to ensure that CO_2 emissions from trade start to decrease.

Keywords: Trade openness, CO_2 emissions, panel data, fixed effects, EKC, Pollution Haven

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1. Introduction

During the last 60 years, both the import and the export of goods and services have increased. From 2005 to 2014, the value of import and export of goods and services had almost doubled (The World Bank Group 2019b, 2019f). Trade openness is a concept to describe the ratio between trade and GDP. It is the sum of export and import as a percentage of GDP. Trade openness has also grown from 2005 to 2014 (The World Bank Group 2019h), and it is apparent that trade is an essential part of the economy today.

CO_2 emissions have also increased during the last 60 years, mainly due to human activities (Intergovernmental Panel on Climate Change (IPCC) 2019). Between 2000 and 2015, the global CO_2 emissions increased by 40 percent (Organisation for Economic Co-operation and Development (OECD Publishing) 2017). The greatest source of CO_2 emissions is the use of energy. However, industry and transport are also large emitters (OECD Publishing 2017). According to a report from the International Energy Agency (IEA) from 2017, transport, including shipping, accounted for 23 percent of the emissions from the energy sector. Shipping accounted for 80 percent of the global trade but only 2 percent of the total CO_2 emissions from fuel combustion (IEA 2017).

In this thesis, we will examine what impact trade openness has on CO_2 emissions. This relationship has previously been studied, with varying results. Environmental scientists, such as Hornborg (2018), argue that trade has a negative impact on the environment. Kolstad (2011) discusses the difficulties in controlling transboundary pollution, such as CO_2 emissions. Antweiler, Copeland and Taylor (2001) and other researcher, argue that trade has a positive impact on the environment. Previous studies have applied different methods and different ways of measuring trade. One way is to use the concept of trade openness, which is used in our study. In addition to using the concept of trade openness, our study contains different variables than previous studies do. Further, Gross National Income (GNI) per capita is used as a measure of income level, instead of GDP per capita, which is usually used.

In recent years, there has been an increasing interest in the effect of trade on emissions. However, little is known about the effect of trade openness on emissions for different income groups based on GNI per capita. Since both CO_2 emissions per capita and world trade have increased over the last decades and still do (The World Bank Group 2019a, 2019h), the plausible correlation between them is an important question now and in the future.

1.1 Purpose

The purpose of this thesis is to examine how trade openness impacts CO_2 emissions. The thesis will also examine whether there is any difference in the studied effect between high-income countries and low-income countries. To achieve this, we analyse the relationship by observing data from 161 countries, over a ten year period, 2005-2014, with different income levels.

To achieve the purpose of the thesis, we aim to answer the following questions:

- What impact does trade openness has on CO_2 emissions?
- Does the impact of trade openness on CO_2 emissions per capita differ between countries with different income levels?

1.2 Disposition

This thesis will start by describing the issue with CO_2 emissions and some factors behind trade. Thereafter, some theories such as the Pollution Haven hypothesis, Race to the Bottom, the Environmental Kuznets Curve and Gains from Trade will be presented. Further, previous studies regarding the theories and the effect of trade on emissions are introduced. The sections after that explain the data used in the regression and the chosen method, panel data. The results from the regression are then presented and interpreted. Lastly, the findings and limitations are being discussed.

2. Background

To get more of an understanding of this subject, some background information regarding CO_2 emissions and trade is presented in this section.

2.1 CO_2 emissions

Since pre-industrial times, the average concentration of CO_2 has increased by 40 percent (OECD Publishing 2017), and in 2017, temperature increase caused by human activities reached 1 degree above pre-industrial levels (IPCC 2019). During a long period of time, it has been the developed countries that have been emitting the most, but in 2015, developing countries were responsible for more than half of the global CO_2 emissions (OECD Publishing 2017). Between 2000 and 2015, emissions have doubled for developing countries. The increase is largely due to development and growth in the economy, technology and demographics for many developing countries. At the same time, emissions from developed countries have declined (OECD Publishing 2017).

The main factor behind the increase in CO_2 emissions is the increasing demand for energy, where the majority of the energy still is produced from fossil fuels. Since 1970, the demand for energy has increased by nearly 150 percent (OECD Publishing 2017). For fuel combustion, in 2015, the largest sources were electricity and heat, transport and industry (OECD Publishing 2017). The industry sector consists of direct and indirect emissions. Direct emissions come from the manufacturing processes of the industry where the majority are due to energy use from fossil fuels. Indirect emissions come from the production of energy, which is later used for the industrial processes (United States Environmental Protection Agency (EPA) 2019).

In 2015, the world's leaders came together in Paris to agree on a global climate agreement to reduce CO_2 emissions. The goal is to keep the temperature increase below 2 degrees Celsius above pre-industrial levels and keep an effort to limit the increase to 1.5 degrees Celsius. One part of the agreement is to provide continued support to developing countries in their environmental work (United Nations Climate Change (UNFCCC) 2019).

With drastic actions in terms of emission reduction, primary in the energy sector, scientists believe that it is possible to reduce CO_2 emissions so that the temperature increase is limited to 1.5 degrees Celsius (IPCC 2019). If the temperature increases by 2 degrees Celsius, there is an increased risk for catastrophic consequences for both humans and ecosystems (IPCC 2019). Changed conditions for agriculture would lead to reduced harvests leading to an increasing number of hungry people in vulnerable areas. Furthermore, extreme weather such as extreme heat, floods, storms and droughts will occur more frequently. People living along the coasts and on low-lying islands will be forced to flee due to sea level rise (IPCC 2019).

2.2 Trade

After the Second World War, some countries started negotiating a trade agreement. The agreement was called the General Agreement on Tariffs and Trade (GATT) and was first signed in 1947. It is still the main treaty within international trade. In 1995, the World Trade Organization (WTO) was created. Today there are 164 member countries, and they represent 98 percent of the world trade (World Trade Organization 2018).

One of the primary benefits of trade is international specialisation and one fundamental model explaining this is the Heckscher-Ohlin model of international trade (Kolstad 2011). According to the model, international specialisation will increase trade because of comparative advantages due to factor endowment (Kolstad 2011). The factor endowment is based on countries having different resources and, therefore, they export goods that they are well adjusted to produce and import goods they can not or are less adapted to produce (Black, Hashimzade & Myles 2017d). In the Heckscher-Ohlin model, the absence of trade would lead to products that require a large amount of labour to be cheaper in labour intensive countries and more expensive in countries with higher capital (Black, Hashimzade & Myles 2017b). This is explained through countries having the same constant-returns-to-scale production functions for a good, but different capital and labour supply. If this model is accurate, this would mean that free trade and no cost for transport would result in the same price for a product all over the world (Black, Hashimzade & Myles 2017b).

3. Theories

The theories presented in this section are the Pollution Haven hypothesis, Race to the Bottom, the Environmental Kuznets Curve and Gains from Trade. These theories will later be used to analyse the results.

There are many theories that can be applied to trade openness. The concept of trade openness, as explained earlier, is the sum of export and import as a share of GDP (The World Bank Group 2019h). One of the most common theories about trade openness is the Pollution Haven hypothesis. The hypothesis is that developed countries have more stringent environmental regulations than what developing countries have and, therefore, the effect is that developing countries get the pollution-intensive production that earlier was located in developed countries, due to freer trade (Copeland & Taylor 2004). Developing countries have a comparative advantage in pollution-intensive production because of less stringent environmental regulation and lower production costs (Copeland & Taylor 2004; Antweiler, Copeland & Taylor 2001). Developed countries import these pollution-intensive goods and instead specialise in clean production due to their comparative advantages because of more stringent environmental regulations. This implies that dirty industries from developed countries relocate to developing countries with weaker environmental regulations when trade increases (Antweiler, Copeland & Taylor 2001). It is, therefore, the differences in regulations and comparative advantages that can be regarded as driven factors behind the hypothesis (Antweiler, Copeland & Taylor 2001).

Race to the bottom is a theory closely related to the Pollution Haven hypothesis and is also about the effect of trade and environmental regulations for developing countries (Copeland &

Taylor 2004). The theory is about developing countries adopting less stringent environmental regulations, due to freer trade, in order to lower their production costs (Copeland & Taylor 2004). This is on purpose to attract international businesses and improve competitiveness on the global market (Frankel & Rose 2005). The intention is, therefore, to take care of the production of pollution-intensive goods, which makes them become pollution havens (Frankel & Rose 2005). Copeland and Taylor (2004) argued that evidence for the Pollution Haven has importance for the interpretation of Race to the Bottom (Copeland and Taylor 2004). If evidence is found for the Pollution Haven, it might be plausible that less stringent environmental regulations, which Race to the Bottom refers to, can be seen as a gap in the restrictions of trade agreements (Copeland and Taylor 2004).

Another theory concerning the effect of trade is Gains from Trade. This theory claims that countries gain from trade because of two factors; the factor endowment and economies of scale (Black, Hashimzade & Myles 2017a). The factor endowment is based on comparative advantages due to countries having different resources (Black, Hashimzade & Myles 2017d). The other factor, the economies of scale (Black, Hashimzade & Myles 2017c), allows larger countries to produce more, and a wider variety of products, cheaper than smaller countries. Both of these effects are claimed to improve the welfare of the country (Black, Hashimzade & Myles 2017c, 2017d). Frankel (2009) addressed that this indicates that a country can get more of what they want, including environmental goods. He, therefore, argued that trade has a positive effect on environmental quality, and this effect can be divided into two parts. The first one is the technological innovation that trade can boost, this will be explained in the literature review. The other one is the possibility of a political jurisdiction or country to set the standards for environmental standards. This is referred to as the California effect within the United States, where California set high standards for auto pollution control equipment (Frankel 2009).

The Environmental Kuznets Curve is a theory about the relationship between environmental quality in a country and the income level of that country. The theory originates from the Kuznets Curve, which is a theory about the relationship between income per capita and income inequality. Grossman and Krueger (1991) observed a similarity between the Kuznets Curve and the relationship between environmental quality and income per capita and since then, there has been a lot of research about this relationship (Dasgupta, Laplante, Wang & Wheeler 2002). The shape of the EKC is an inverted U-shape (Grafton et al. 2004), which is an identical shape as the Kuznets Curve. The theory is that when developing countries become richer, they will damage the environment increasingly until a tipping point. This tipping point is usually assumed to be between 5 000-8 000 dollars in income per capita (Dasgupta et al. 2002). After this tipping point, the country will start decreasing their environmental degradation. The reasoning behind this differ. According to Grafton et al. (2004), some researchers argue that when the country develops from agriculture to more industry, the country will become richer but also more damaging to the environment until it reaches a tipping point. Thereafter, a higher income level will result in better technology for the environment (Grafton et al. 2004). Others argue that this is a result of a shift in priorities from jobs and income to the environment as the country becomes richer (Dasgupta et al. 2002). Cole (2004), however, examined if the Pollution Haven hypothesis could be an explanatory factor to the shape of the EKC-curve for developed countries. If developed countries move their pollution intensive production to developing countries, they would reduce emissions in their home countries and this would explain the EKC (Cole 2004).

4. Literature review

There has been a lot of research about the effect of trade on emissions, and the relationship between income level and emissions. In this section, some previous studies that are relevant for the purpose of this study are introduced.

In 1991, Grossman and Krueger published a working paper on the relationship between air quality and economic growth. This has since then been viewed as the origin of the Environmental Kuznets Curve. They conducted a cross-section study for SO_2, dark matter and the mass of suspended particles in the air. They chose not to do this study on CO_2 due to data availability and the reliability of the data. They found evidence that the concentration of both SO_2 and dark matter first increased with GDP at low-income levels but then decreased at high-income levels. They also found that the mass of the suspended particles in the air was decreasing with GDP (Grossman & Krueger 1991). Since then, there have been several studies on the relationship between income level and different pollutions, with different results.

Previous research regarding the EKC have had mixed results. Cole (2003) and Schmalensee, Stoker and Judson (1998) both found evidence that supports the EKC. Cole (2003) found a statistically significant inverted U-shape between income and CO_2 emissions. His results suggested that narrowing the group of countries to only developed, developing or OECD countries almost did not have an effect on the results, contrary to what other researchers have argued. Schmalensee, Stoker and Judson (1998) found an inverted U-shape when focusing on CO_2 emissions produced by the combustion of fossil fuels. Roberts and Grimes (1997) investigated low-, medium- and high-income countries and found that only the high-income countries had a net improvement in CO_2 emissions. They observed that some wealthy countries were improving but the majority of countries were getting worse. Azomahou, Laisney and Van (2006) found evidence that contradicts EKC. They found that a higher income level resulted in higher CO_2 emissions.

Antweiler, Copeland and Taylor (2001), who examined the relationship between trade and environmental impact, divided this impact into three parts; scale, composition and technique effects. These three effects have also been used by Grossman and Krueger (1991) in their study about trades impact on the environment. The scale of economic activity extends by trade, which leads to an increasing level of production in the country (Antweiler, Copeland & Taylor 2001). This leads to an increase in emissions, the scale effect has, therefore, a negative impact on the environment. The second effect is the composition effect, which could have both negative and positive impacts on the environment depending on the country's comparative advantage. Since trade causes specialisation, the country will increase its production in sectors where they benefit from their comparative advantages. If the country specialises in production with high pollution intensity, due to its comparative advantages, the composition effect has a negative impact on the environment. The last of the three effects is the technique effect. When income increases due to trade, economic growth increases in the country. The potential output from this is greener production techniques with lower pollution intensity. The technique effect has, therefore, a positive impact on the environment and decreases emissions (Antweiler, Copeland & Taylor 2001). Antweiler, Copeland and Taylor (2001) did not measure trade as openness since they argue that the impact of openness on a country's composition differs among countries. Instead, they based their study on the characteristics of the countries. The overall conclusion from Antweiler, Copeland and Taylor (2001) findings was that trade had a positive effect on the environment. SO_2 was the only pollution they measured and they did not find any evidence for the Pollution Haven hypothesis.

Frankel and Rose (2005) examined the effect of trade openness on the environment and found different results depending on which pollution was measured. The most relevant pollutions, according to them, measured in the study were nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and particulate matter (PM). For all three air pollutions, the coefficient was negative, indicating that when trade increased, these pollutions decreased. When they measured the effect of trade on CO_2 emissions, they found a significant and positive effect, unlike the other pollutions. Frankel and Rose (2005) argued that one explanation for the varying results was that CO_2 is a global externality and have a global negative impact compared to the other pollutions where the negative impact mostly is local. They further examined the EKC and found that the results for NO_2, SO_2 and PM confirmed the theory. However, the results for CO_2 did not support the EKC since the variable for income per capita squared was positive and, therefore, did not indicate an inverted U-shape. Moreover, they tested the Pollution Haven hypothesis by interacting trade openness with income per capita, measured as GDP per capita. They found no evidence to support the hypothesis since the interaction term was insignificant for most pollutions. The exception was for SO_2 and PM, which got significant coefficients. The effects were although positive, which is the opposite effect than what it should have been to be able to support the hypothesis (Frankel & Rose 2005).

5. Data

The following section presents and explains the data used in this study. Thereafter, a correlation analysis and the descriptive statistics are presented and discussed.

5.1 Data

The first step in this study was to collect relevant data. All data were collected from The World Bank (The World Bank Group 2019a, 2019c, 2019e, 2019g, 2019h, 2019i). Since this study focuses on CO_2 emissions, over a ten year period, the dependent variable in the regression is CO_2 emissions (metric tons per capita). To examine the relationship between trade openness and CO_2 emissions, data for trade openness were collected. Trade openness is, as mentioned earlier, the sum of export and import as a percentage of GDP (The World Bank Group 2019h). This definition of trade openness has been used by researches as Frankel and Rose (2005) and Ertugrul Cetin, Seker and Dogan (2016). Besides trade openness, GNI per capita (calculated with the World Bank Atlas method), GDP per capita, GDP per capita squared, urban population as a percentage of total population and industry (including construction) as value added as a percentage of GDP, were chosen as independent variables. From now on, these variables will be referred to as trade openness, GNI per capita, GDP per capita, GDP per capita squared, urban population and industry. A variable description is presented in Appendix 1. As explained in the background section, the industry is a large source of CO_2 emissions. Therefore, it is included as one of the control variables in the regression. The other control variable is urban population since urbanisation contributes to increased emissions (The World Bank Group 2010). To limit the data, and to get balanced data, only countries with data for all variables and for all ten years were included in this study.

Previous studies on the Pollution Haven hypothesis, as earlier explained in the theory section and in the literature review, have used GDP per capita and trade openness as an interaction term to study the effects of trade on CO_2 emissions. In this study, GNI per capita is used instead of GDP per capita in the interaction term. The reason behind this is that The World Bank uses GNI per capita as a classification for income level (calculated with the World Bank Atlas method). The definition of GNI is the sum of GDP and the net receipts of primary income from abroad (The World Bank Group 2019e). The World Bank (n.d.b) divides the countries into four groups: low-income, lower-middle-income, upper-middle-income and high-income. The low-income countries are those with a GNI per capita of 995 U.S. dollars or less. The countries with a GNI per capita between 995 U.S. dollars and 3 895 U.S. dollars are considered as lower-middle-income, and those between 3 896 and 12 055 U.S. dollars are considered as upper-middle-income countries. The high-income countries are those with a GNI per capita higher than 12 056 U.S. dollars (The World Bank Group n.d.b). This division is used in this study as an attempt to examine if the effect of trade openness differs between low-income and high-income countries.

In Appendix 2, all 161 countries included in this study are presented. Since the countries vary in the income level over time, they can be included in different income groups in different years. In total, 44 countries are included in the group of low-income countries, 71 in lower-middle-income countries, 62 in upper-middle-income countries and 53 in the group of high-income countries, at some point in time.

Since there might be correlation between the variables, a correlation analysis were conducted and is presented in Appendix 3. It shows that there is no high correlation between the independent variables, expect the correlation between GDP per capita, GDP per capita squared and GNI per capita. This is to be expected since all three of them measure some of the same values for an economy. Since they are highly correlated, both GDP per capita and GNI per capita should not be included in the regression. GDP per capita is the most recognized variable in previous studies to test EKC and has been used by researchers such as Grossman and Krueger (1991) and Frankel and Rose (2005). Therefore, it is included in the regression instead of GNI per capita. However, to measure the effect of trade openness on CO_2 emissions for different income levels, GNI per capita as a dummy will be applied. For this reason, both GNI per capita as a dummy and GDP per capita are included in the regression. We, therefore, conducted a regression when GNI per capita and GNI per capita squared were applied instead of GDP per capita and GDP per capita squared. The result from this is shown in Appendix 4 and implies that the main finding from the regression is the same, with some small differences. This supports that GNI per capita as a dummy, GDP per capita and GDP per capita squared can all be used in the regression.

5.2 Descriptive statistics

Table 1 shows the descriptive statistics for the variables in this study and Appendix 5 and 6 present the descriptive statistics for the four different groups of income level for CO_2 emissions per capita and trade openness. The data in table 1 presented as 'overall' is the mean value, maximum value and minimum value overall for all observations. The data presented as 'between' is between individuals and the data presented as 'within' is over time. One interesting observation from the descriptive data is that the minimum and maximum values, for all variables, differ a lot. The reason for this is that the data consists of a variety of countries, both low-income countries and high-income countries. The data was examined for any outliers and even though there is a big difference in the minimum and maximum values, the data does not contain any outliers. Appendix 5 and 6 show that the mean of both trade openness and CO_2 emissions are increasing with the four different income groups. For trade openness, the difference between lower-middle-income and upper-middle-income is almost non-existent, while there is a clear difference between all income groups for CO_2 emissions.

Table 1 Descriptive statistics

Variable		Mean	Std. Dev.	Min	Max	Observation
CO_2 emissions per capita	overall	4.14	4.67	0.02	25.36	N = 1 610
(metric tons per capita)	between		4.63	0.03	21.68	n = 161
	within		0.67	-3.23	11.25	T = 10
Trade openness	overall	91.53	55.14	0.17	442.62	N = 1 610
(% of GDP)	between		53.91	10.47	391.49	n = 161
	within		12.27	16.76	226.25	T = 10
GDP per capita	overall	12 839.47	18 711.36	150.49	118 823.60	N = 1 610
(current US$)	between		18 441.50	215.16	105 346.50	n = 161
	within		3 453.72	-17 322.39	51 623.46	T = 10
GNI per capita	overall	12 244.72	17 534.64	130.00	104 540.00	N = 1 610
(current US$)	between		17 331.82	205.00	87 443.00	n = 161
	within		2 958.37	-11 408.28	40 306.72	T = 10
Industry	overall	26.85	13.19	2.53	85.66	N = 1 610
(% of GDP)	between		12.96	6.03	80.13	n = 161
	within		2.64	7.87	38.75	T = 10
Urban population	overall	56.09	22.72	9.38	100.00	N = 1 610
(% of total)	between		22.74	10.54	100.00	n = 161
	within		1.36	50.14	61.87	T = 10

Source: Own calculations from Stata. All numbers are rounded to two decimals

6. Methodology

In this section, the regression model and the method for this study are presented. Furthermore, some econometric concerns regarding the method are being discussed.

6.1 Econometric model

This thesis is an empirical study based on secondary data. To analyse the effect of trade openness on CO_2 emissions, 161 countries were compared over a ten year period, 2005-2014. All the calculations were estimated in the statistical analysis software program Stata.
The regression for this study is the following:

$$\begin{aligned} \ln(CO_2\ per\ capita)_{it} = {} & \alpha_i + \beta_1 * trade\ openness_{it} \\ & + \beta_2 * (GNI\ per\ capita(as\ dummy)_{it} * trade\ openness_{it}) \\ & + \beta_3 * \ln(GDP\ per\ capita)_{it} \\ & + \beta_4 * \ln(GDP\ per\ capita^2)_{it} + \beta_5 * industry(\%\ of\ GDP)_{it} \\ & + \beta_6 * urban\ population_{it} + u_{it} \end{aligned}$$

The coefficients of the main interest in this study are β_1 and β_2. Since β_1 measures the effect of trade openness on CO_2 emissions per capita, it aims to answer the first research question. β_2 is the interaction term between trade openness and GNI per capita. It consists of four dummies where the countries have been divided into four different income levels. This term aims, therefore, to answer the second research question whether the effect of trade openness on CO_2 emissions differs between countries with different income levels. The interaction term also tests the Pollution Haven hypothesis and should be negative for the high-income group when the low-income group is the control group, to be able to support the hypothesis. β_3 is the coefficient for GDP per capita. GDP per capita squared, β_4, shows if the marginal effect of GDP per capita is constant. If β_4 is significant, the marginal effect is not constant. If β_3 is significant and positive, and if β_4 is significant and negative, it would confirm that the effect is not constant and therefore, confirm the EKC. Industry, β_5, and urban population, β_6, are included in the regression as control variables to avoid omitted variable bias. α_i is the individual-specific intercept for each country and the error term, u_{it}, consists of unobserved variables. The variables CO_2 emissions per capita and GDP per capita is being logged in order to be able to interpret these variables in percentage. The other variables are already measured in percentage and are, therefore, not being logged.

6.2 Panel data

Panel data is considered as the most appropriate model to use when observing multiple individuals over time. One advantage with panel data, compared to time series or cross-sectional data, according to Verbeek (2017), is that panel data makes it possible to observe changes on an individual level. Therefore, panel data makes it possible to explain why individuals act as they do and also to explain why they behave differently at different time periods. Compared to cross-sectional and time series, panel data can observe more observations from the same sample. This can provide more information and more efficient estimators (Verbeek 2017). In a standard linear regression, *i* is an index for an individual and *t* is an index for a time period. *y* measure the dependent variable, *x* symbolize all the independent variables and ε is the error term. The standard linear regression can, therefore, be given by:

$$y_{it} = \beta_0 + x'_{it}\beta + \varepsilon_{it}$$

One problem with using a standard linear regression is the assumption of unbiasedness, consistency and efficiency (Verbeek 2017). Since the observations are over time, there could be a high likeliness of correlation between the variables over time. To control for this problem there are two methods; the fixed effects model and the random effects model (Verbeek 2017).

To be able to determine whether to use the fixed effects model or the random effects model, the Hausman-test can be applied (Verbeek 2017). The test consists of a null hypothesis which states that the estimates of both models are consistent. If the null hypothesis cannot be rejected, it means that the data is not endogenous and that the random effects model should be applied. If the null hypothesis is rejected, the fixed effects model should be applied instead (Verbeek 2017). The p-value in the test we conducted was close to 0, and therefore, the null hypothesis could be rejected. We could, therefore, apply the fixed effects model in our study.

In the fixed effects model, the problem with correlation within an individual over time can be controlled by using an individual-specific interception term in the regression (Verbeek 2017). The assumption for the fixed effects model is that the individual-specific effect is correlated with one or more of the independent variables. The estimates of the fixed effects model are then consistent (Verbeek 2017). The fixed effects model also produces unbiased estimates when all explanatory variables, for all individuals for all years, are independent with all the error terms (Verbeek 2017). The general regression for panel data when using the fixed effects model is:

$$y_{it} = \alpha_i + x'_{it}\beta + u_{it}$$

α_i is the individual-specific intercept for individual i and is often referred to as fixed effects (Verbeek 2017). Since each individual has a unique intercept, the fixed effects model do not have a β_0, which is usually used in a standard linear regression (Verbeek 2017).

In the random effects model, it is assumed that all variables that have an effect on the dependent variable, but is not included, can be summarised in a random error term (Verbeek 2017). The individual-specific effects that the fixed effects model controls for are instead treated as random in the random effects model and are included in the error term. α_i can be assumed to be random factors, independently and identically distributed between individuals (Verbeek 2017). The regressions for the random effects model can, therefore, be described as:

$$y_{it} = \beta_0 + x'_{it}\beta + \alpha_i + u_{it}$$

Where $\alpha_i + u_{it}$ is the error term. α_i is assumed to not vary over time and to be individual-specific. u_{it} on the other hand, is assumed to be uncorrelated over time (Verbeek 2017).

6.3 Concerns regarding the method

A common problem with panel data is that the data set often has missing observations for some country over time, which means that the data is unbalanced (Verbeek 2017). Since all countries in our study have observations for all years, the data is strongly balanced.

In this study, CO_2 emissions are assumed to be the dependent variable of x'_{it}. This would suggest that there is causality, x'_{it} affect the dependent variable and not the other way around (Westerlund 2005). However, there are some threats against this assumption. There might be reversed causality, which means that the effect is the opposite (Verbeek 2017). There is no proof that CO_2 emissions do not have an effect on x'_{it}, for example, GDP per capita. Another threat against the assumption of causality is omitted variable bias. This implies that the explanatory variables could be correlated with some unobserved factors in the error term. These are factors that also could have an effect on the dependent variable (Verbeek 2017). Therefore, we can not be certain that there is causality in our regression.

A problem when computing a regression can, as mentioned, be omitted variables (Verbeek 2017). When a relevant variable is unobserved, it is called a omitted variable (Westerlund 2005). A variable is relevant when it is correlated with one of the other variables, and excluding it would, therefore, invalidate the exogeneity assumption, $E[u \mid X] = 0$. If there are omitted variables, it indicates that there is an omitted variable bias in the regression. This could lead to a variable coefficient being estimated as more substantial than it is, or the coefficient could have the wrong sign (Westerlund 2005). A variable is strictly exogenous in panel data if it does not depend on the value of the error term, u_{it}, now, in the past nor in the future (Gujarati & Porter 2009). The expression for this is $E[u_{it} | \, x'_{it}] = 0$. If the variables are endogenous, there could be a unit root (Gujarati & Porter 2009). Another reason why the variables could be endogenous is unobserved heterogeneity. Unobserved heterogeneity can appear when individuals, or in this case, countries, are being observed over time (Gujarati & Porter 2009). A consequence of this could be that the observed variables are correlated with the unobservable factors in the error terms (Gujarati & Porter 2009). Panel data, however, take this into account in a regression, which differs from time-series and cross-sectional data which do not (Baltagi

2001). When not controlling for unobserved heterogeneity, the results from the estimates can be biased (Baltagi 2001).

If the error terms between observations in a regression are correlated, there is autocorrelation (Verbeek 2017). If the data is collected in a random way, it is assumed that there is no autocorrelation. Within panel data, however, it is expected to be autocorrelation. One form of autocorrelation is first-order autocorrelation. A common way to test for first-order autocorrelation when using panel data is the Durbin-Watson test. One of the reasons there could be autocorrelation is if there are any omitted variables (Verbeek 2017). Since it is assumed to be autocorrelation in panel data, there is most likely autocorrelation in this regression, but this is not controlled for in this study.

Heteroskedasticity is when the error terms are uncorrelated, but the variance of the error terms vary over the observations (Verbeek 2017). If there is a high variance, this means that the observations are further away from the true regression line than if there is a small variance. The opposite, when the variance of the error term does not differ, is called homoskedasticity (Verbeek 2017). In this study, it could mean that the error term has a larger variance for the high-income countries than for the low-income countries. Heteroskedasticity could, therefore, be a problem in this study. To control for any presence of heteroskedasticity, Gujarati and Porter (2009) advises the use of robust standard errors, also called White's heteroskedasticity-corrected standard errors. Therefore, robust standard errors were added in the regression for this study.

Another aspect to take into account, when conducting a regression, is that multicollinearity can occur if two or more explanatory variables in the regression are strongly related to each other Gujarati & Porter 2009). Some level of multicollinearity is often common, but at high levels, it can result in unsafe estimates. One way to solve this problem is to test the correlation between all variables and exclude those that are highly correlated (Gujarati & Porter 2009). The correlation analysis for this study is shown in Appendix 3.

7. Results

In this section, the results from the regression are presented and analysed and the research question are being answered.

The results from our estimations are shown in table 2. To answer the first research question about what impact trade openness has on CO_2 emissions, the coefficient for trade openness, β_1, will be analysed. To answer the second research question, whether the effect of trade openness on CO_2 emissions differs between countries with different income levels, the coefficient for the interaction term, β_2, will be analysed. The significant levels and the robust standard errors are shown in table 2.

Table 2 Regression results

Variable	lnCO_2 emissions per capita
Trade openness	0.0011**
	(0.0005)
GNI per capita (high-income) * trade openness	-0.0015**
	(0.0006)
GNI per capita (upper-middle-income) * trade openness	-0.0006
	(0.0005)
GNI per capita (lower-middle-income) * trade openness	-0.0003
	(0.0004)
GNI per capita (low-income) * trade openness = o	-
lnGDP per capita	0.8444***
	(0.2543)
lnGDP per capita squared	-0.0395***
	(0.0149)
Industry	0.0038
	(0.0025)
Urban population	0.0113*
	(0.0062)
Constant	-4.4223***
	(1.0155)
Observations	1,610
Number of country	161
R-squared	0.2259

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations from Stata

As can be seen from table 2, the coefficient for trade openness, β_1, is significant and positive. This indicates that when trade openness increased by one unit, in this case, 1 percent of GDP per capita, CO_2 emissions increased with 0.11 percent metric tons per capita on average. Trade openness had, therefore, a negative impact on the environment.

From the interaction term between trade openness and income level, β_2, the difference in the marginal effect of trade openness on CO_2 emissions between the different income levels can be interpreted. The interaction term for the group of countries with low GNI per capita, low-income countries, was the control group and was therefore omitted. The other three groups were the treatment groups. It can be seen from the regression results in table 2 that the only interaction term with a significant result was the group with high GNI per capita, high-income countries. As the coefficient for the interaction term with trade openness and high GNI per capita was negative, the marginal effect of trade openness was lower for high-income countries compared with low-income countries. The difference in the marginal effect of trade openness on CO_2 emissions between high-income countries and low-income countries, given by β_2, was on average 0.15 percent metrics tons per capita. These results imply that when trade openness increased with one additional unit for both a high-income country and a low-income country, CO_2 emissions increased on average with 0.15 percent less for the high-income country than for the low-income country. The marginal effect of trade openness on CO_2 emissions for a high-income country was the sum of the coefficient for trade openness, β_1, and the coefficient for the interaction term, β_2. The marginal effect was then -0.04 percent metric tons per capita on average for a high-income country. Since low GNI per capita was the control group, the interaction term was zero. Therefore, the marginal effect for low-income countries was the coefficient for trade openness, β_1, and was 0.11 percent metric tons per capita on average. As the results show, CO_2 emissions increased for low-income countries and decreased for high-income countries, when trade openness increased. This is in line with the Pollution Haven hypothesis.

The coefficient for GDP per capita, β_3, was positive and significant. CO_2 emissions, therefore, increased with 0.84 percent metric tons per capita on average when GDP per capita increased with one percent. However, the effect of GDP per capita was not constant since GDP per capita squared was significant. This coefficient, β_4, was negative. These results showed that for each additional percentage increase in GDP per capita, the marginal effect decreased. This is consistent with the EKC since it indicates an inverted U-shape.

The control variable urban population, β_6, was positive and significant. This implies that when urban population increased with 1 percent of the total population, CO_2 emissions increased with 1.13 percent metric tons per capita on average. Industry, the other control variable, β_6, was not significant.

8. Discussion

This section starts by analysing the main findings from the results and compare these with the previous studies and theories applied in this study. In addition, limitations regarding this study are being discussed.

8.1 Analysing the results

The main finding from the results was that trade openness had a positive effect on CO_2 emissions per capita on average and, therefore, a negative impact on the environment. This finding, that CO_2 increased when trade increased, support what Hornborg (2018) argues that free trade continues to be a source to the emissions.

Since this study was based on 161 countries with different income levels and other differences such as political, geographically and different prerequisites, these results can be seen as quite general and not the complete explanation. If assumed that countries with the same income level have some general characteristics in common, a more precise outcome could be analysed from the interaction term. It can be concluded that the effect of trade openness on CO_2 emissions differs between countries with high- or low-income levels. The difference in the effect of trade openness on CO_2 emissions between high-income countries and low-income countries was small but significant.

When we examined the Pollution Haven hypothesis by interacting income level and trade openness, we got a significant effect. We can from this finding conclude that trade openness increased CO_2 emissions for low-income countries while it decreased CO_2 emissions for high-income countries. Regarding the Pollution Haven hypothesis, these results are consistent with the basic idea of the theory that low-income countries become dirtier when trade increases in that country. However, the theory is based on arguments about environmental regulations, something we have not accounted for in this study. It is, therefore, difficult to say anything about our results based on this aspect of the theory. If assumed that high-income countries are having more stringent environmental regulations than low-income countries (Antweiler, Copeland & Taylor 2001; Copeland & Taylor 1994), then the results are consistent with the Pollution Haven hypothesis. According to previous studies, it can be difficult to find evidence to support the Pollution Haven hypothesis. This can, according to Antweiler, Copeland and Taylor (2001), be because of comparative advantages and that this affects the change in the composition of a country's production that trade openness causes.

It is quite difficult to examine evidence for the theory Race to the Bottom in our results since we have not measured environmental regulations. This is similar to the interpretation of the Pollution Haven hypothesis. In that interpretation, we assumed, as earlier researchers also have (Antweiler, Copeland & Taylor; Copeland & Taylor 2004), that low-income countries have less stringent environmental regulations than high-income countries have. As explained earlier in the theory section, Copeland and Taylor (2004) argued that for the interpretation of Race to the Bottom, evidence for the Pollution Haven is of relevance. Since our results showed that the emissions increased for low-income countries when trade openness increased, we could say that this is in line with the Pollution Haven hypothesis, according to the assumption that was made. It might, therefore, be possible that low-income countries have weakened their environmental regulation on purpose to attract international business. However, this assumption is dependent on several assumptions, and therefore, we can not say that we find any evidence for supporting the theory of Race to the Bottom based on the content of our study.

The results in this study also indicate an inverted U-shape since the marginal effect of GDP per capita on CO_2 emissions was not constant and decreased over time. Our results are in line with results from Schmalensee, Stoker and Judson (1998) and Cole (2003) who also found evidence for the EKC. Roberts and Grimes (1997) found a net improvement in CO_2 emissions for the high-income countries and that is also in line with our results. In our study, however, there are four income groups which differs from Roberts and Grimes (1997) since they had three income groups instead of four. Another difference was that they did not conduct their study based on trade and GNI. As mentioned earlier, the results from previous EKC research are mixed, and therefore, our result was similar to some research but differed from others. What can be concluded is that an inverted U-shape was found in our study, which supports the EKC.

Gains from Trade, as mentioned earlier, is a theory about countries gaining from trade, and increasing their welfare, due to the economies of scale effect and comparative advantages.

Frankel (2009) argued that because of the improvement in welfare, countries could get more environmental goods. If assumed that higher GDP also indicates higher welfare, the non-constant effect of GDP in this study could be explained. Countries increasing their GDP could be getting more environmental goods that emit less CO_2. Then, the marginal effect of GDP would decrease. This could be one explanation of why this study found evidence for the EKC.

The results from the estimation that trade openness increased CO_2 emissions on average is consistent with what Frankel and Rose (2005) found in their study. While CO_2 emissions increased in their study, all the others measured pollutions, such as SO_2, NO_2 and PM, decreased. Frankel and Rose (2005) argued that a possible explanation for the increase of CO_2 emissions was the global negative impact CO_2 emissions have on the environment. This could, according to Frankel and Rose (2005), be seen as a free-rider problem and means that there is small incitement for individual countries to reduce their emissions since the emissions cross national borders. Since Antweiler, Copeland and Taylor (2001) measured SO_2 as the only pollution in their study, it is, therefore, a bit misleading to compare our results with their findings. They further divided the impact of trade into three parts, which altered the impact in different ways. Their study had, therefore, several aspects, including comparative advantages of the countries. If we had based our study on these three effects, the results might have been different.

8.2 Limitations

We chose the concept of trade openness to measure trade since it is an accepted definition from The World Bank. Since it includes both import and export as a percentage of GDP, there could be a difference in the results if trade openness were to be divided into two separate measurements. One for export as a share of GDP and another for import as a share of GDP. Consider two countries where one country has a high share of import and the other country has a high share of export, but they both have the same size of trade openness. The country with a high share of import would have less CO_2 emissions since the measure of emissions only includes domestic production. In that case, it seems that high trade openness does not lead to high CO_2 emissions. The other country with a high share of export has a high amount of CO_2 emissions since it produces a lot. In this case, high trade openness instead leads to high CO_2 emissions. Antweiler, Copeland and Taylor (2001) were critical about the concept of trade openness. As explained earlier, they argued that the way openness affect countries differ due to comparative advantages.

Another limitation of this thesis was the choice of pollutions and control variables. The only pollution measured in this study was CO_2 emissions. In many previous studies, several pollutions were included in the estimations, such as SO_2 and NO_2. If we had included some more pollutions in this study, more comparisons with some previous studies could have been made, for example with Antweiler, Copeland and Taylor (2001), that only measured SO_2.

Transport, deforestation and energy consumption or production, are some examples of control variables that probably might have an effect on CO_2 emissions. This paper did not account for these variables due to data availability. All of those variables could be assumed to have a positive effect on emissions. Another aspect this study did not take into consideration was the differences in environmental regulations between countries. It can be assumed that developing countries have less environmental regulation than developed countries have (Copeland and Taylor 2004; Antweiler, Copeland and Taylor 2001). If this assumption holds, then environmental regulation could be considered controlled for when observing different groups of income levels.

We are aware that the four groups of income levels did not contain the same quantity of countries. The main reason behind not excluding countries, to get an equal division among the groups, was that several countries shifted from one income level to another during the time period, 2005-2014. Most countries shifted to a higher income level and some to a lower. It would, therefore, be challenging to get a perfectly balanced division without removing too many countries. Removing several countries from the data could affect the results. However, we are aware that the unbalance between the groups also could have an effect on the results.

There might be some issues when using GNI per capita as a measurement of income level. Neither GNI, nor GDP, take into account how the income is distributed between individuals. GNI can, therefore, not completely represent a country's level of welfare and development (The World Bank Group n.d.a). The GINI index, which is an index for how equal the distribution of income level is (The World Bank Group 2019d) might, therefore, have been an interesting alternative or addition to GNI per capita.

Another weakness of this study could be the econometric concerns regarding the method. Some of the concerns are not being controlled for and, therefore, this might have had an effect on the results.

During 2007 and 2008, there was a global financial crisis that affected trade. In 2008, when trade as a percentage of GDP was at its highest, it was 60.83 percent. In 2009, after the financial crisis, it was 52.31 percent, and in 2010, it was 56.82 percent (The World Bank Group 2019h). Trade still has not entirely recovered from the crisis. The results of this study might, therefore, have been affected by the crisis. To control for this, the years 2009 and 2010 were excluded in the regression presented in Appendix 7. As the result shows, these years did not have a big effect on the results and can, therefore, be included in the regression.

9. Conclusion

This section summarises the results of this study and briefly discusses what aspects further research could focus on.

The aim of this research was to examine the effect of trade openness on CO_2 emissions. The panel data regression analysis revealed that trade openness did have an impact on CO_2 emissions. When trade openness increased, CO_2 emissions increased and had, therefore, a negative impact on the environment, which is consistent with some previous studies such as Frankel and Rose (2005). The results further revealed that there was a significant difference in this impact between low-income countries and high-income countries. The emissions increased for low-income countries and decreased for high-income countries when trade openness increased.

We found evidence supporting the EKC since the effect of GDP per capita on CO_2 emissions was not constant and the effect decreased over time. Since we found that emissions decreased for high-income countries and increased for low-income countries when trade openness increased, this is in line with the basic idea of the Pollution Haven hypothesis. However, we did not account for environmental regulations in this thesis, which the Pollution Haven hypothesis is based on. Therefore, we based our results on the assumption that low-income countries have less stringent environmental regulations than high-income countries have.

This study contributes to previous research. However, the main weakness of this study compared to previous research was the limitations in data availability. It is unfortunate that the study did not include other variables that might have had an effect on the results. Despite its limitations, this study offers some insight into the relationship between trade and CO_2 emissions. Further research could include other control variables in the regression such as transport, energy use, deforestation and environmental regulation. They could also focus on various pollutions to get a broader analysis.

If the results from this study are correct, it implies that CO_2 emissions increase when trade openness increases for low-income countries. For policymakers, this means that greater efforts are needed to make sure that trade does not continue to be a source of CO_2 emissions. It is then important with a greater focus on environmental aspects in trade agreements between low-income countries and high-income countries.

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Appendix 1 – Variable description

Variable	Description
CO_2 emissions per capita	Carbon dioxide emissions, measured as metric tons per capita
Trade openness	Sum of import and export of goods and services, measured as % of GDP
GNI per capita (high-Income) * trade openness	Interaction term for trade openness for high-income countries (GNI per capita of 12 056 or higher)
GNI per capita (upper-middle-income) * trade openness	Interaction term for trade openness for upper-middle-income countries (GNI per capita between 3 896 and 12 055 US dollar)
GNI per capita (lower-middle-income) * trade openness	Interaction term for trade openness for lower-middle-income countries (GNI per capita between 995 and 3 895 US dollar)
GNI per capita (low-income) * trade openness	Interaction term for trade openness for low-income countries (GNI per capita of 995 US dollar or less)
GDP per capita	Gross domestic product divided by midyear population, measured in current US dollar
GDP per capita2	The squared of GDP per capita
Industry	Industry including construction, value added, measured in current US dollar
Urban population	People living in urban areas, as % of total population

Source: The World Bank Group 2019a, 2019c, 2019d, 2019f, 2019g, 2019h

Appendix 2 – List of countries

Country Name			
Angola	Denmark	Kiribati	Portugal
Albania	Dominican Republic	St. Kitts and Nevis	Paraguay
United Arab Emirates	Algeria	Korea, Rep.	Romania
Argentina	Ecuador	Lao PDR	Russian Federation
Antigua and Barbuda	Egypt, Arab Rep.	Lebanon	Rwanda
Australia	Spain	Liberia	Saudi Arabia
Austria	Estonia	St. Lucia	Sudan
Azerbaijan	Finland	Sri Lanka	Senegal
Burundi	Fiji	Luxembourg	Singapore
Belgium	France	Latvia	Sierra Leone
Benin	Micronesia, Fed. Sts.	Macao SAR, China	El Salvador
Burkina Faso	Gabon	Morocco	Slovak Republic
Bangladesh	United Kingdom	Moldova	Slovenia
Bulgaria	Georgia	Madagascar	Sweden
Bahamas, The	Ghana	Mexico	Eswatini
Bosnia and Herzegovina	Guinea	Marshall Islands	Chad
Belarus	Gambia, The	North Macedonia	Togo
Belize	Guinea-Bissau	Mali	Thailand
Bolivia	Greece	Malta	Tajikistan
Brazil	Grenada	Myanmar	Turkmenistan
Barbados	Guatemala	Mongolia	Timor-Leste
Brunei Darussalam	Guyana	Mozambique	Tonga
Bhutan	Hong Kong SAR, China	Mauritania	Tunisia
Botswana	Honduras	Mauritius	Turkey
Central African Republic	Croatia	Malawi	Tanzania
Switzerland	Haiti	Malaysia	Uganda
Chile	Hungary	Namibia	Ukraine
China	Indonesia	Niger	Uruguay
Cote d'Ivoire	India	Nigeria	United States
Cameroon	Ireland	Nicaragua	Uzbekistan
Congo, Dem. Rep.	Iran, Islamic Rep.	Netherlands	St. Vincent and the Grenadines
Congo, Rep.	Iceland	Norway	Venezuela, RB
Colombia	Israel	Nepal	Vietnam
Comoros	Italy	New Zealand	Vanuatu
Cabo Verde	Jamaica	Oman	Samoa
Costa Rica	Jordan	Pakistan	South Africa
Cuba	Japan	Panama	Zambia
Cyprus	Kazakhstan	Peru	Zimbabwe
Czech Republic	Kenya	Philippines	
Germany	Kyrgyz Republic	Palau	
Dominica	Cambodia	Poland	

Source: The World Bank Group 2019a

Appendix 3 – Correlation analysis

Variables	CO_2 emissions per capita	Trade openness	GDP per capita	GDP per capita2	GNI per capita	Industry	Urban population
CO_2 emissions	1.0000						
Trade openness	0.2540	1.0000					
GDP per capita	0.6612	0.3089	1.0000				
GDP per capita2	0.5006	0.3020	0.9126	1.0000			
GNI per capita	0.6537	0.2760	0.9895	0.8693	1.0000		
Industry	0.2534	-0.0259	-0.0483	-0.0758	-0.0495	-1.0000	
Urban population	0.5919	0.2702	0.5936	0.4077	0.6018	0.1318	1.0000

Source: Own calculations from Stata

Appendix 4 – Regression results when GDP per capita is replaced by GNI per capita

Variable	lnCO_2 emissions per capita
Trade openness	0.0014**
	(0.0005)
GNI per capita (high-income) * trade openness	-0.0018***
	(0.0006)
GNI per capita (upper-middle-income) * trade openness	-0.0009
	(0.0005)
GNI per capita (lower-middle-income) * trade openness	-0.0005
	(0.0004)
GNI per capita (low-income) * trade openness = o	-
lnGNI per capita	0.893***
	(0.240)
lnGNI per capita squared	-0.0423***
	(0.0145)
Industry	0.0041*
	(0.0024)
Urban population	0.0094
	(0.0059)
Constant	-4.530***
	(0.978)
Observations	1 610
Number of country	161
R-squared	0.241

Robust standard errors in parentheses

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

Source: Own calculations from Stata. All numbers are rounded to four decimals

Appendix 5 – Descriptive statistics for CO_2 emissions

Variable: CO_2 emissions Income level		Mean	Std. Dev.	Min	Max	Observations
Low-income	overall	0.32	0.58	0.02	4.54	N = 309
	between		0.84	0.03	4.51	n = 44
	within		0.05	0.09	0.52	T = 7.02
Lower-middle-income level	overall	1.66	1.90	0.16	12.58	N = 448
	between		2.35	0.21	12.15	n = 71
	within		0.30	-0.39	5.26	T = 6.31
Upper-middle-income level	overall	4.39	3.25	0.82	15.65	N = 407
	between		3.49	0.84	14.75	n = 62
	within		0.39	1.20	7.58	T = 6.56
High-income level	overall	9.07	4.94	1.97	25.36	N = 446
	between		4.85	2.25	21.68	n = 53
	within		1.09	1.70	13.17	T = 8.42

Source: Own calculations from Stata. All numbers are rounded to two decimals

Appendix 6 – Descriptive statistics for trade openness

Variable: Trade openness Income level		Mean	Std. Dev.	Min	Max	Observations
Low-income	overall	70.13	37.04	0.17	311.35	N = 309
	between		35.97	0.21	176.64	n = 44
	within		16.83	3.71	204.85	T = 7.02
Lower-middle-income level	overall	86.61	32.57	0.20	194.35	N = 448
	between		31.43	25.86	156.84	n = 71
	within		8.73	60.18	140.79	T = 6.31
Upper-middle-income level	overall	86.67	33.43	22.11	203.85	N = 407
	between		32.09	24.90	167.99	n = 62
	within		8.17	56.99	124.29	T = 6.56
High-income level	overall	115.73	83.71	24.49	442.62	N = 446
	between		80.01	25.45	391.49	n = 53
	within		12.48	40.96	177.14	T = 8.42

Source: Own calculations from Stata. All numbers are rounded to two decimals

Appendix 7 – Regression results when the years 2009 and 2010 are excluded

Variable	$lnCO_2$ emissions per capita
Trade openness	0.0010*
	(0.0006)
GNI per capita (high-income) * trade openness	-0.0015**
	(0.0006)
GNI per capita (upper-middle-income) * trade openness	-0.0006
	(0.0005)
GNI per capita (lower-middle-income) * trade openness	-0.0003
	(0.0004)
GNI per capita (low-income) * trade openness = o	-
lnGDP per capita	0.8742***
	(0.2503)
lnGDP per capita squared	-0.0412***
	(0.0147)
Industry	0.0033
	(0.0026)
Urban population	0.0111*
	(0.0062)
Constant	-4.5044***
	(1.0104)
Observations	1 288
Number of country	161
R-squared	0.2518

Robust standard errors in parentheses

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

Source: Own calculations from Stata. All numbers are rounded to four decimals