The effect of environmental policies on CO_2 emissions

Using the environmental policy stringency index

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Abstract:

The carbon concentration in the air has increased by 50 percent since pre-industrial times and continues to increase every year. Climate change is, therefore, a significant challenge today. The purpose of this paper is to study how the stringency of the environmental policies affect carbon dioxide emissions, and what factors play the most important part in influencing different countries' carbon emissions trajectory. Built on the environmental policy stringency index constructed by OECD, this paper applies a panel data model with fixed effects to a sample with 33 countries between 1990 and 2014. The results show that higher stringency of environmental policies does not have a significant impact on carbon dioxide emissions, while fossil fuel consumption and gasoline price influence carbon dioxide emissions the most. The results imply that lowering fossil fuel consumption by increasing gasoline prices could be a solution in an attempt to reduce carbon dioxide emissions.

Keywords: Environmental policy stringency index, CO_2 emissions, panel data, fixed effects

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1 Introduction

One of the most challenging problems the world is facing today is climate change. The concentration of greenhouse gases in the atmosphere, particularly carbon dioxide (CO_2) emissions, has increased from below 300 ppm to over 400 ppm, which is the highest level in the past 800,000 years. The increasing concentration of CO_2 has resulted in an increased temperature by 1.1 degrees Celsius since pre-industrial times. Such changes in the atmosphere and temperature are damaging and cause extreme weather, such as floods, storms, and heatwaves (Ritchie & Roser 2019).

Several environmental policies are implemented all around the world in an attempt to reduce greenhouse gas emissions. Nations and countries are setting different targets and implementing various solutions to reduce emissions. Examples of implementations are legislation for increasing the use of renewable energy, a cap and trade system where industries are allowed a certain amount of emissions and putting a price on carbon through a carbon tax. New technologies have also been developed, and one example is the carbon capture and storage (European Environment Agency 2019). To measure the effect of environmental policies, many of the previous studies have examined carbon taxes, which has resulted in varying outcomes. Bohlin (1998) concluded that a carbon tax did not affect emissions in the transport sector, while Andersson (2019) found a significant reduction in CO_2 emissions after implementing a carbon tax. Another measure of environmental policies is the environmental policy stringency (EPS) index, which is an international comparable policy index (OECD 2020). Ahmed and Ahmed (2018) used the EPS index between the years 1990 and 2012 to predict annual CO_2 emissions in China between 2012 and 2022, which resulted in a simulated reduction in CO_2 emissions. To the best of my knowledge, other studies using the EPS index have been done, however, not to evaluate the effect on CO_2 emissions.

The purpose of this study is to examine how the stringency of environmental policies, proxied by the Environmental Policy Stringency (EPS) index, affect CO_2 emissions, and what factors are the most crucial in influencing the CO_2 emissions. It is essential to identify the factors affecting the CO_2 emissions, to be able to reduce the risks associated with climate change. The EPS index is a preferable measure in studying this question in that it provides a comparable measure of the stringency of environmental policies across countries.

This study uses a panel data model to analyze how the EPS index affects CO_2 emissions between 1990 and 2014. The related conceptual framework is built on the Environmental Kuznets Curve which reflects the relationship between CO_2 emissions and income. The results show that there is no significant relationship between the EPS index and the CO_2 emissions, while fossil fuel consumption and gasoline price are significant and thus are associated with CO_2 emissions. An increased fossil fuel consumption increases the CO_2 emissions, while an increased gasoline price reduces the CO_2 emissions. The results also show that there is no relationship between CO_2 emissions and income, and therefore no support for the Environmental Kuznets Curve in this study. One of the potential explanations is that the EPS index captures many types of regulations and not only the ones associated with CO_2 emissions.

The following sections start with a background on CO_2 emissions and environmental policies, followed by a literature review. Thereafter I present relevant theories on the Environmental Kuznets Curve. Then I introduce the data and empirical strategy, followed by results, discussion, and a conclusion.

2 Background

2.1 Carbon dioxide emissions

Greenhouse gas emissions contribute to global warming, causing huge environmental problems (Statistiska Centralbyrån [SCB] 2019). Emissions, mainly CO_2 emissions, cause a change of the chemical composition in the air, increasing the temperature of the planet's surface (Naturvårdsverket 2019). Since pre-industrial times, the global average temperature has increased by 1.1 degrees Celsius. The temperature has increased more in the Northern Hemisphere with an average of 1.4 degrees compared to the Southern Hemisphere that has an average increase of 0.8 degrees (Ritchie & Roser 2019). The CO_2 content has increased by 50 percent since pre-industrial times and continues to increase by 0.4 percent every year. Total global CO_2 emissions every year is approximately 35 billion tons, a high increase compared to the 2 billion tons of CO_2 emitted in 1900 (Naturvårdsverket 2019; Ritchie & Roser 2019).

The primary source of CO_2 emissions, with 87 percent, is fossil fuel consumption (Le Quéré et al. 2012). The most used fossil fuels are coal (43 percent), oil (36 percent), and natural gas (20 percent) (International Energy Agency 2012). Fossil fuels are mainly used for electricity, heat, and transportation (Le Quéré et al. 2012). The transportation sector uses petroleum-based fuels such as gasoline and diesel. The emissions from the transport sector have increased by 45 percent in less than 20 years due to increased transports (International Transport Forum 2010). Other sources of CO_2 emissions are land use such as agriculture, and industrial processes such as the production of mineral products, metals, chemicals, and petrochemical products (Le Quéré et al. 2012).

The CO_2 emissions can be measured in both per capita and annually. Countries with high CO_2 emissions per capita are Australia (average of 17 tons per capita), the United States (average of 16.2 tons per capita), and Canada (average of 15.6 tons per capita). Their average CO_2 emissions per capita are considerably higher than the global average per capita of 4.8 tons. When looking at total CO_2 emissions annually, Asia is the largest emitter with around half of the global CO_2 emissions, with China as the largest emitter with 10 billion tons. The second-largest emitter is North America, with 18 percent of total global CO_2 emissions, with the United States as the largest emitter. Europe is the third-largest emitter globally with 17 percent, and Africa and South America together emit around 6 to 8 percent of the global CO_2 emissions. Even if Asia emits about 50 percent, they have 60 percent of the world's population while North America emits 18 percent and only has 5 percent of the world's population. The outcome when measuring total annual CO_2 emissions and CO_2 emissions per capita are, therefore, different, according to Ritchie and Roser (2019).

Ritchie and Roser (2019) argue that there is a strong correlation between GDP per capita and CO_2 emissions per capita, which means that countries with a high standard of living emit more. However, they also point out that European countries with a high standard of living emit much less per capita than Australia, the United States, and Canada. The reason for this is due to reduced production of fossil fuel, and increased production of renewable and nuclear energy, as well as increased technological efficiency (Ritchie & Roser 2019).

2.2 Environmental policies

Different environmental policies have been implemented in an attempt to reduce greenhouse gas emissions. The first legal treaty to reduce emissions, the Kyoto Protocol, was established in 2005. The purpose was for industrialized countries to reduce their emissions by an individual set target. Countries can, thereafter, implement specific policies to achieve these individual targets. The first commitment period was between 2008 and 2012, where 37 industrialized countries and the European Union agreed to reduce emissions by an average of 5 percent compared to 1990 (United Nations Framework Convention on Climate Change [UNFCCC] 2020). The European Union, EU-15 at the time, implemented individual targets to reduce emissions by an average of 8 percent, and in the end, achieved a reduction of 11.7 percent. The Kyoto Protocol covered only 18 percent of total global emissions since the world's largest emitters were not part of the treaty (European Commission 2020). The second commitment period started in 2013 and is active until the end of 2020, where the 192 parties are reducing emissions by 18 percent compared to 1990 (UNFCCC 2020). The European Union and Iceland have individual targets of reducing emissions by 20 percent compared to 1990 (European Commission 2020).

To achieve the targets in the Kyoto Protocol, in the year 2000, the European Commission analyzed the most appropriate policies and instruments to reduce greenhouse gas emissions under the name of the European Climate Change Programme (ECCP). This search for relevant policies resulted in the EU Emissions Trading System (ETS), launched in 2005. The EU ETS is a cap and trade system, where the cap is the total amount of greenhouse gas emissions allowed. Companies can receive, buy, and trade caps, allowing a certain amount of emissions. The cap is reduced over the years, which reduces the total amount of greenhouse gas emissions. If companies exceed their allowed emissions, they will have to pay a large fine. In the first phase between 2005 and 2007, emissions had to be estimated due to missing reliable data and therefore resulted in allowances issued exceeding emissions. In phase 2, between 2008 and 2012, reliable data on emissions were available, and allowances issued were reduced. Due to the economic crisis in 2008, emissions were reduced drastically, and allowances exceeded emissions again. According to the European Commission (2020), ETSs are cost-effective because of the flexibility of trading, allowing emissions to be reduced where it costs the least. The EU ETS is the largest carbon market and covers 45 percent of the EU's emissions (European Commission 2020).

The ETS is one way to put a price on carbon through industries, and the other way of pricing carbon is with a carbon tax. A carbon tax is a price on the carbon content, common in fossil fuels (The World Bank 2020). Putting a tax on the carbon content is a way to make the polluter pay, and an incentive to develop new technologies and increase the use of renewable alternatives. The revenues from the carbon tax can be used for purposes related to the carbon tax, such as funding other environmental issues (Swedish Government 2020). Around 40 countries, 20 cities, states, and provinces are using a carbon pricing method, which covers half of their CO_2 emissions, and about 13 percent of total global CO_2 emissions (The World Bank 2020).

A similar regulation to the ETS is the Effort Sharing Decision (ESD), launched in 2013, for EU countries, including Norway and Iceland. This policy includes most sectors that are not included in the ETS, such as transportation, construction, agriculture, and waste. The first period is between 2013 and 2020, and how emissions change compared to 2005. Every member has a specific target based on their GDP per capita. The change of emissions ranges between a reduction of 20 percent for the highest income country and an increase of 20 percent for the lowest-income country. The low-income countries are allowed an increase in emissions to ensure they can continue their economic growth (European Commission 2020).

Another policy is the Paris Agreement, implemented in November 2016, which in May 2019 had 185 countries agreeing to the policy. The most fundamental parts of the agreement are to keep global warming at a level below 2 degrees Celsius, reevaluate every five years starting in 2023, and support developing countries (Naturvårdsverket 2019). If all countries in the Paris Agreement succeed with their targets, the estimated global warming in 2100 compared to pre-industrial times will be 2.6-3.2 degrees Celsius, compared with the existing environmental policies of 3.1-3.7 degrees Celsius. However, if there were no environmental policies, global warming would be estimated to 4.1-4.8 degrees Celsius (Ritchie & Roser 2019).

2.3 Literature review

There have been many studies to measure the effect of environmental policies on emissions. Studies on carbon taxation are many, while fewer studies using the environmental policy stringency (EPS) index have been done, especially to evaluate the effect on CO_2 emissions. Ahmed and Ahmed (2018) used the EPS index in a study to predict annual CO_2 emissions in China until 2022. The correcting grey model was used, with the EPS index and gross domestic product (GDP) as controlling variables between 1990 and 2012. The simulated results between 2012 and 2022 showed that more stringent environmental policies reduced CO_2 emission (Ahmed & Ahmed 2018).

Studies on the effect of a carbon tax on emissions in different countries have been done using different methods and treatment periods, which resulted in different outcomes. Lin and Li (2011) studied the effect of a carbon tax on emissions in Sweden, Norway, Denmark, Finland, and the Netherlands. They used the difference-in-difference (DiD) method, and the result for Finland showed a significant reduction in CO_2 emissions per capita of 1.69 percent after the carbon tax was implemented, compared to what it would have been without the carbon tax. For Sweden, Denmark, and the Netherlands, it also resulted in a reduction, but none of them were significant, which shows a carbon tax had a limited effect in reducing CO_2 emissions. The result for Norway shows the opposite, an insignificant increase in CO_2 emissions per capita, which concludes that the carbon tax has no impact in Norway. Another study in Norway between 1990 and 1999 used applied general equilibrium (AGE) to estimate the effect on CO_2 emissions after implementing a carbon tax. The results showed that the carbon tax on fuel had a small impact due to tax exemptions and inelastic demand in this sector (Bruvoll & Larsen 2004).

Stanislav and Speck (2018) studied the effect of a carbon tax on CO_2 emissions in Sweden between 1961 and 2012, using Granger causality. The results showed that there was no granger causality between the carbon tax and the CO_2 emissions, implying that the carbon tax did not affect CO_2 emissions. Another study made in Sweden on the effect of a carbon tax on emissions using ex-post evaluation comparing the year 1990 to the year 1995, concluded that the total reduction in all sectors was 0.5 to 1.5 million tons of carbon dioxide per year. However, in the transport sector, the carbon tax did not affect emissions (Bohlin 1998). A recent study in Sweden analyzed how CO_2 emissions were affected after introducing a carbon tax on transport fuel. To estimate the change in CO_2 emissions, Andersson (2019) used panel data and a synthetic control method using comparable countries to Sweden that did not implement any policies during the treatment period, 1990 to 2005. After implementing the carbon tax, the CO_2 emissions were reduced by an average of 6.3 percent per year. This study is the first to find a significant result for Sweden.

Murray and Rivers (2015) found that after introducing a carbon tax in British Columbia, Canada, in 2008, the emissions were reduced by 5-15 percent. The results were obtained by taking the difference of a simulated model with and without the tax. The tax covered all fossil fuels, which was around 70-75 percent of the province's emissions. From the start in 2008, there were no tax exemptions, but in 2012 and two years forward of the study, there were some tax exemptions made.

3 Theory

3.1 Environmental Kuznets Curve

Ritchie and Roser (2019) argue that income and emissions are highly correlated, and higher income countries, therefore, emit more than less developed countries. Higher income countries can, however, decrease their emissions because they increase their use of environmentally friendly fuels such as renewable energy (Ritchie & Roser 2019). To analyze how emissions change after income, I will use the theory on the Environmental Kuznets Curve (EKC) to analyze the results.

The theory on the Environmental Kuznets Curve shows the relationship between pollution and income as an inverted U-shaped curve. The theory developed from the Kuznets Curve, which shows the relationship between development and economic inequality. When a country starts its industrialization, pollution increases faster. The pollution increases because income is more important for people than the environment. Hence, the country will not be able to make the necessary precautions to tackle air pollution, nor will they be able to provide clean water. Furthermore, environmental regulations are not stringent at this point. As a country becomes more prosperous and enters an industrialized economy, a clean environment becomes higher valued, and environmental regulations are implemented. At this point, there will be a turning point where the pollution starts to decrease. The turning point is suggested to take place when a country reaches around 5,000 to 8,000 dollars per capita. When the income reaches beyond this, the pollution will start to decrease (Dasgupta, Laplante, Wang & Wheeler 2002).

Critics of the Environmental Kuznets Curve have argued that the EKC just shows a small sequence of a dynamic process. They mean that the EKC will develop to a horizontal line when reaching maximum pollution, similar to the "Race to the Bottom," which focuses on globalization. Others argue that even if some pollutants are reduced when income increases, industries will emit other pollutants. These pollutants could continue to grow and be even more damaging to the environment (Dasgupta et al. 2002).

The literature on the EKC provides mixed results. Apergis and Payne (2009) examine whether there is evidence to support EKC in six countries in Central America between 1971 and 2004. They use a panel vector error correction model. The results show a long run relationship between CO_2 emissions, energy use, and real output. Energy use has a positive and significant effect on emissions, and the real output shows a quadratic relationship. From the results, the conclusion is that the EKC does exist in the six countries in Central America between 1971 and 2004 since the emissions increase real output, which stabilizes, and then starts to decline. Increasing real output reduces emissions because as income increases, so does the demand for higher environmental quality. In the short run, the results show that energy consumption and growth increase emissions (Apergis & Payne 2009).

Al-Mulali, Saboori, and Ozturk (2015) study whether the EKC can be found in Vietnam between 1981 and 2011. They use the method Autoregressive Distributed Lag (ARDL) to determine a pollution model. The results show that fossil fuel consumption increases pollution, while renewable energy consumption has no significant effect in reducing pollution. From the results, the conclusion is that the EKC does not exist in Vietnam between 1981 and 2011, since the correlation between income and pollution is positive both in the short run and the long run (Al-Mulali, Saboori, & Ozturk 2015).

4 Data

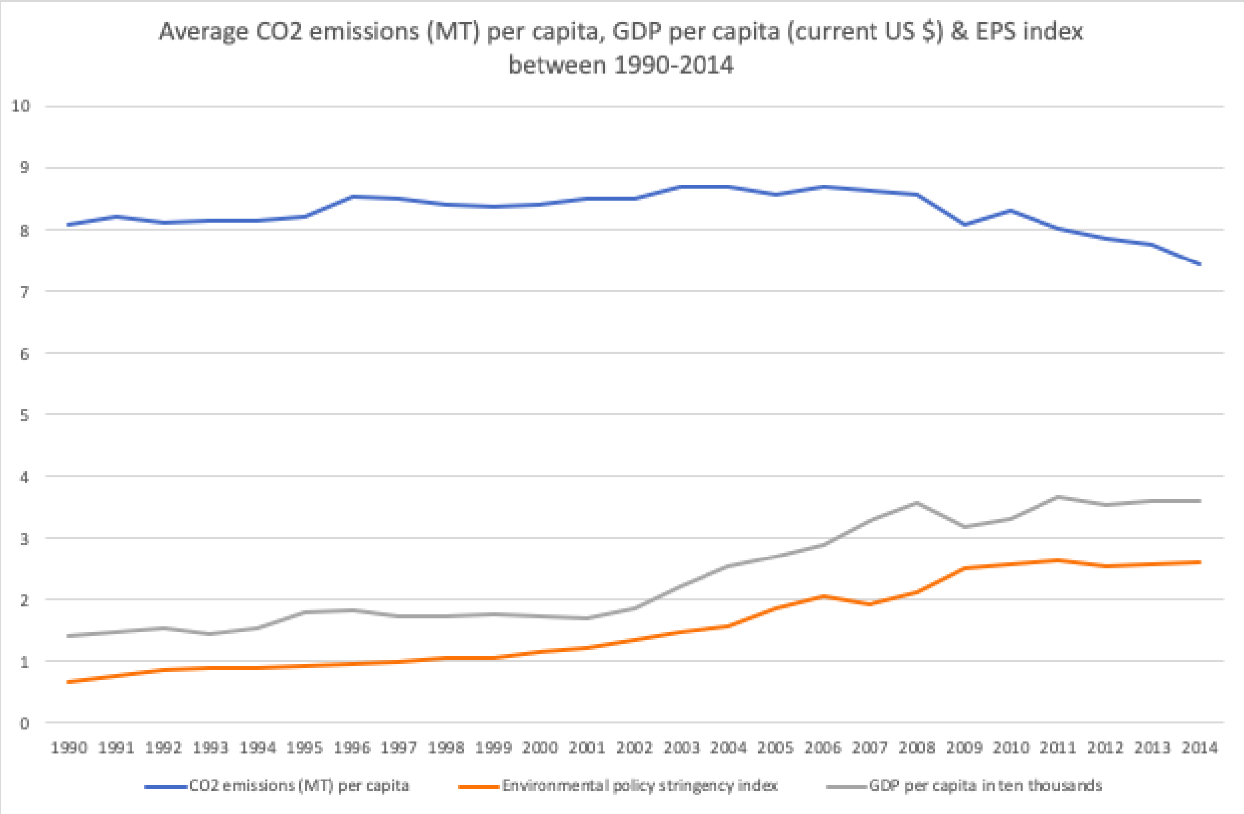
4.1 Data collection

To study the relationship between the stringency of environmental policies and CO_2 emissions, I collect the data from two different sources. The environmental policy stringency (EPS) index comes from OECD (2020). The data for CO_2 emissions, urban population, GDP, fossil fuel consumption, and gasoline and diesel prices are retrieved from the World Bank (2020). The data set includes 33 countries observed between the years 1990 and 2014. The list of countries included in this study can be seen in Appendix 1.

4.2 Variables

In this study, the outcome variables are total annual CO_2 emissions and CO2 emissions per capita; both measured in metric tons (MT). One variable that likely affects CO_2 emissions is population, which is why CO_2 emissions per capita and total annual CO_2 emissions are the dependent variables in different regressions. CO_2 emissions come from fossil fuels and the manufacture of cement, and also includes the CO_2 emissions being produced while consuming solid, liquid, and gas fuels and gas flaring (World Bank 2020). In Figure 1, one can observe the CO_2 emissions per capita and the EPS index as an average between 1990 and 2014. GDP per capita is shown in tens of thousands in current US dollars.

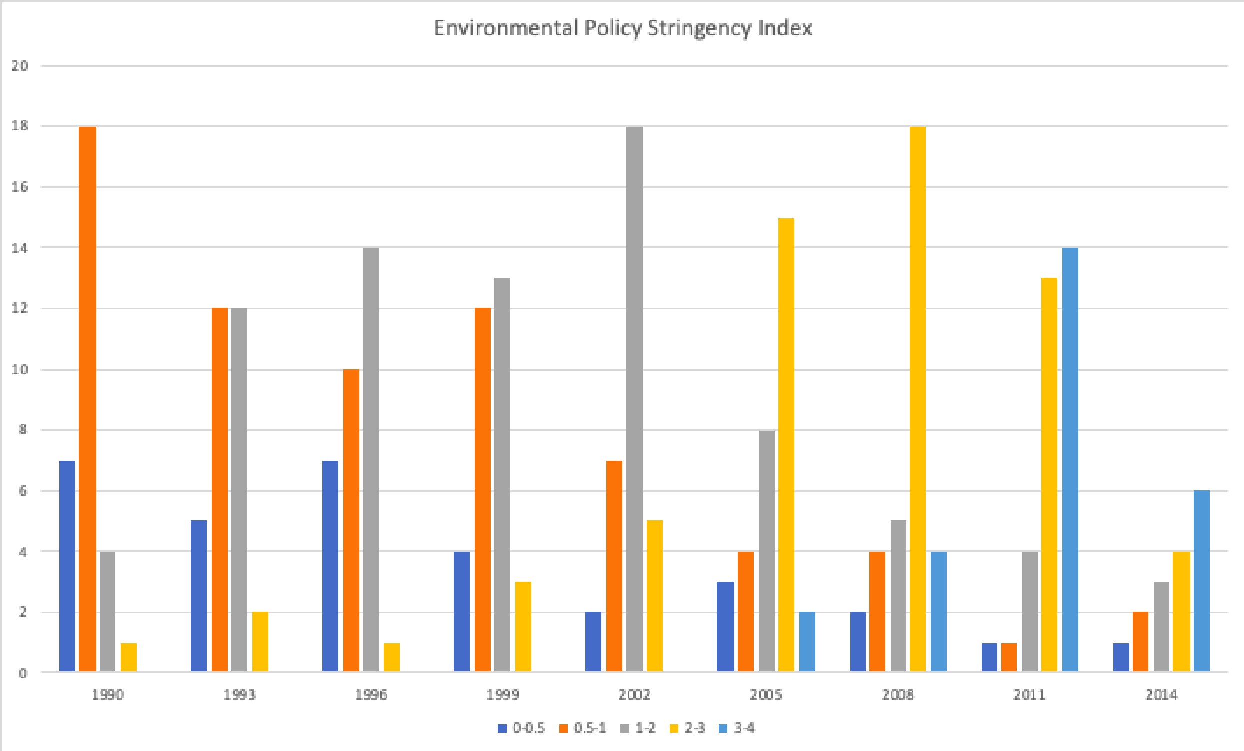
Figure 1: Average CO_2 emissions (MT) per capita, GDP per capita (current US $) & EPS index between 1990-2014



Source: Data from OECD 2020 and the World Bank 2020

To analyze how CO_2 emissions are affected by environmental policies, the environmental policy stringency (EPS) index is used as the independent variable of this study. The EPS index is collected from OECD (2020) and is an international comparable policy index. The stringency of environmental policies is the level of price for polluting or harming the environment. The index ranges between 0 and 6, where a higher EPS index means more stringent environmental policies. The EPS index is based on 14 environmental policy instruments associated with climate and pollution (OECD 2020). In Figure 2, the EPS index has been divided into five groups depending on the level of stringency, and how they vary every three years between 1990 and 2014.

Figure 2: Environmental Policy Stringency Index



Source: Data from OECD 2020

To examine what other factors play a role in affecting CO_2 emissions, I also include control variables; urban population, GDP, fossil fuel consumption, gasoline and diesel prices. I collected the data from the World Bank (2020). A complete variable description can be found in Appendix 2.

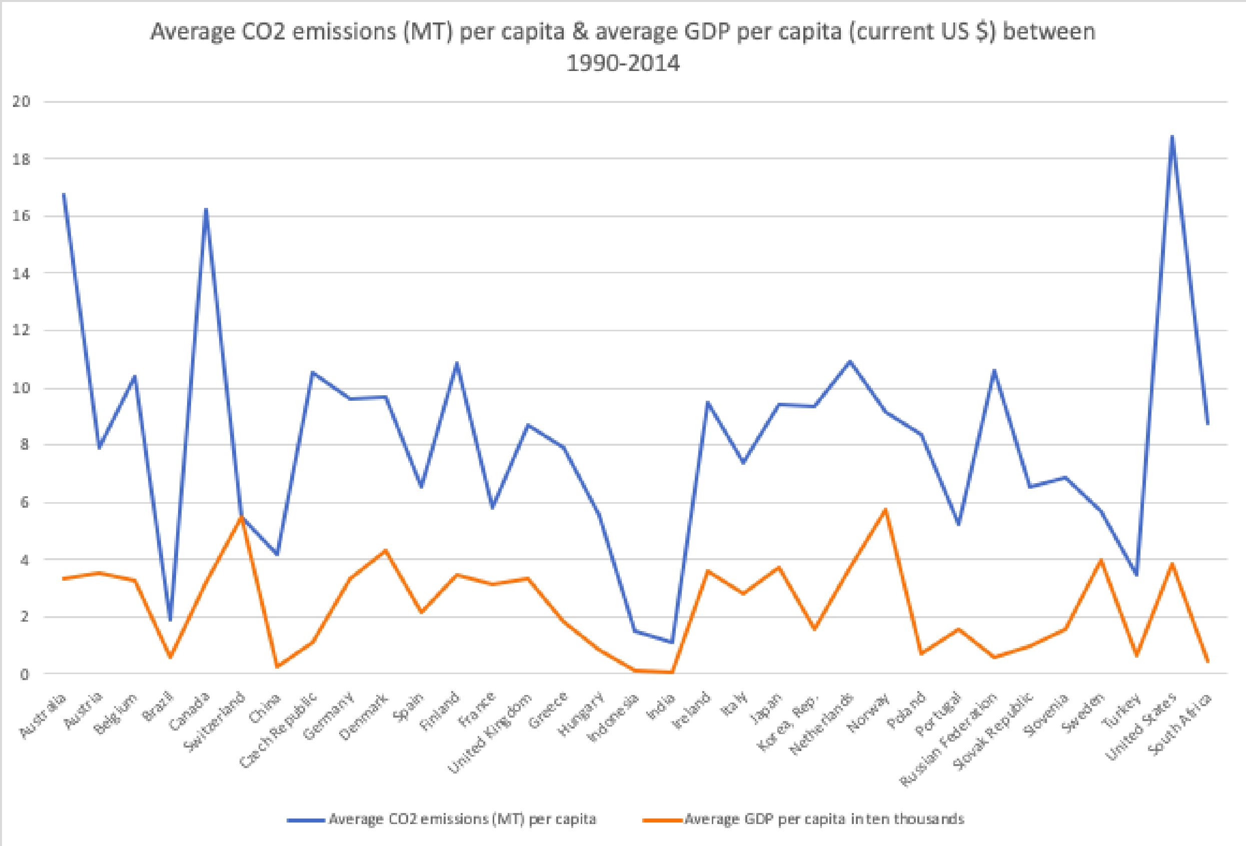
According to Khoshnevis Yazdi and Dariani (2019), the urban population contributes to the increase of CO_2 emissions, and is, therefore, included in the regressions in percentage of the total population. As mentioned in the background section, Ritchie and Roser (2019) argue that there is a strong relationship between high income and emissions. To control for this, the data on the gross domestic product (GDP) is included as both GDP per capita and GDP annually in current US dollars. Ritchie and Roser (2019) also point out that higher income countries emit less than lower income countries. To see if there is a marginal effect of GDP in the regressions, GDP squared is included. This will also help when examining if the Environmental Kuznets Curve exists in the regressions.

As mentioned in the background section, fossil fuel consumption is the primary source of CO_2 emissions (Le Quéré et al. 2012). The variable fossil fuel consumption is, therefore, included in the regressions in the percentage of total fuel consumption. Fossil fuel consumption consists of products from coal, oil, petroleum, and natural gas. The total fuel consumption includes the use of fuel from the start before it is transformed, to the end, when it is transformed into electricity and refined petroleum products. The total fuel consumption also includes renewable fuels and waste (World Bank 2020). Since higher fossil fuel consumption causes higher CO_2 emissions, fossil fuel consumption will be a part of the CO_2 emissions. The fossil fuel consumption will therefore be excluded in the first two sets of the regressions.

A large part of fossil fuel consumption is transportation with the use of gasoline and diesel (Le Quéré et al. 2012). To examine if the demand for gasoline and diesel are affected by prices and causing a change in CO_2 emissions, the price for gasoline and diesel are included in the regressions per liter in current US dollars as a yearly average. According to Bruvoll and Larsen (2004) and Morris (2014), the demand for fuel for cars tends to be very inelastic, meaning that increasing prices in fuel have a small effect on demand. Important to note is that different environmental policies, for example, the carbon tax, are giving a higher fuel price. Environmental policies, such as the carbon tax, are already measured in the EPS index. The gasoline and diesel prices will therefore be excluded in the first set of the regressions.

In Figure 3, GDP per capita and CO_2 emissions per capita are shown as an average for each country between 1990 and 2014. GDP per capita is shown in tens of thousands in current US dollars.

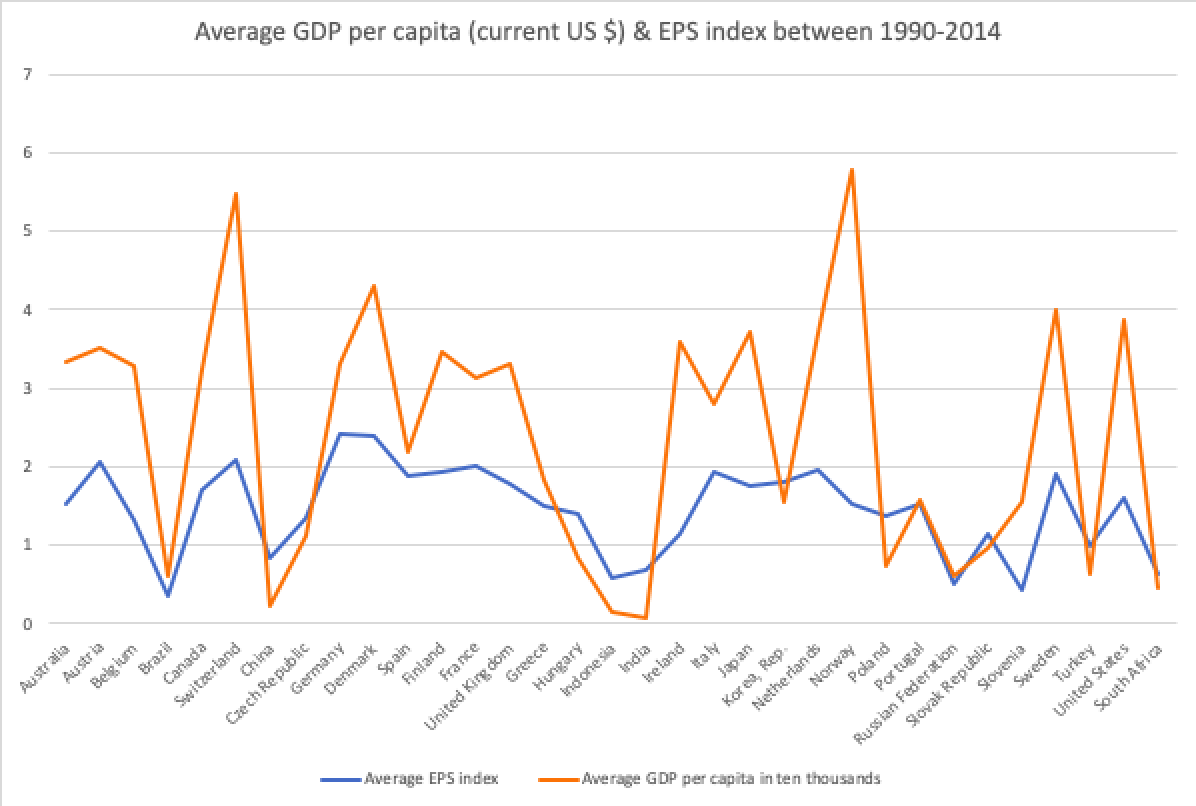
Figure 3: Average CO_2 emissions (MT) per capita & average GDP per capita (current US $) between 1990-2014



Source: The World Bank 2020

In Figure 4, GDP per capita and the EPS index are shown as an average for each country between 1990 and 2014. GDP per capita is shown in tens of thousands in current US dollars.

Figure 4: Average GDP per capita (current US $) & EPS index between 1990-2014



Source: Data from OECD 2020 and the World Bank 2020

4.3 Descriptive statistics

The data is used in a panel data regression and is strongly balanced even if some data are missing. The number of observations can be seen in Table 1 of the descriptive statistics. The variables that are not in percentage already are logged in the program Stata to be able to see the changes in percentage. All regressions are made in Stata.

A total of eight regressions will be conducted. The first two regressions include all 33 countries. The next two regressions include OECD countries, followed by two regressions including non-OECD countries. The final two regressions include high-income countries and low-income countries. The first six regressions will be made with the dependent variable in both CO_2 emissions per capita and total annual CO_2 emissions, and the last two regressions will be made with the dependent variable CO_2 emissions per capita.

The summary statistics are displayed in Table 1, and the results are rounded to two decimals. The variable *EPS index* shows a range between 0.21 and 4.13 with a mean of 1.57, which implies that there are more countries within the lower half of the EPS index. The variable *CO_2 emissions per capita* range between 0.71 MT per capita for India and 20.18 MT per capita for the United States. This variable is not affected by the population since it is measured per capita. The variable *CO_2 emissions annually* range between 1.25×10^7 MT annually for Slovenia and 1.03×10^{10} MT annually for China.

Table 1: Descriptive Statistics

Variable	**Obs**	**Mean**	**Std.Dev.**	**Min**	**Max**
Environmental policy stringency (EPS) index	765	1.57	.95	.21	4.13
CO_2 emissions per capita (metric tons (MT) per capita)	816	8.28	4.08	.71	20.18
CO_2 emissions annually (metric tons (MT) annually)	816	6.43×10^8	1.36×10^9	1.25×10^7	1.03×10^{10}
GDP per capita (current US$)	824	23958.02	18705.36	301.16	103000
GDP (current US$)	824	1.17×10^{12}	2.25×10^{12}	1.27×10^{10}	1.75×10^{13}
Fossil fuel consumption (% of total)	825	76.71	15.28	29.78	98.53
Urban population (% of total)	825	69.95	15.04	25.55	97.83
Gasoline price (pump price per liter in current US$)	335	1.19	.51	.16	2.54
Diesel price (pump price per liter in current US$)	335	1.07	.52	.06	2.35

Source: Own calculations from Stata

4.4 Limitations

This study evaluates the effect of more stringent environmental policies on CO_2 emissions, which includes all environmental policies. As most studies use a carbon tax to evaluate CO_2 emissions, the findings are not always fully comparable. Many studies, as can be seen in the literature review section, only evaluate the changes in CO_2 emissions; however, many of them also used a carbon tax to measure the effect on CO_2 emissions. Some studies have also included other emissions; for example, Bruvoll and Larsen (2004), includes not only CO_2 emissions but also nitrous oxide and methane. Measuring all emissions using the EPS index, which consists of all environmental policies, could instead capture more changes than only measuring the CO_2 emissions.

A variable that could play a role in the results is the crude oil price. Stanislav and Speck (2018) found that a higher oil price was essential to reduce CO_2 emissions. Instead of crude oil prices, gasoline and diesel prices are included. Other variables that also could be included are electricity and heat prices since those also are a part of fossil fuel consumption (Le Quéré et al. 2012).

When analyzing non-OECD countries, only six countries were studied, which is a small data set. When analyzing countries after income, they were divided into two groups, low and high-income countries, instead of more income groups, due to few countries studied. Adding more data in the data set will make the regressions perform better and the outcome more reliable.

5 Method

5.1 Panel data

When observing multiple individuals over time, panel data is the most suitable method. Compared to cross-sectional data or time series, the repeated observations in panel data makes it possible to observe more observations from the same sample and changes on an individual level, that is, why individuals behave differently at different times. Panel data also gives more variability, less collinearity between the variables, and more degrees of freedom, which gives efficient estimators and more information. Panel data propose that individuals are heterogeneous. If this is not controlled for in time series and cross-sectional data, it could lead to biased results (Baltagi 2005; Verbeek 2004).

A linear model in panel data is defined in equation (1), where i is the index for different individuals, and t is the index over time. The dependent variable is y, and the independent variable is x, β is the partial effect of x, and ε is the error term.

$$y_{it} = x'_{it}\,\beta_{it} + \varepsilon_{it} \tag{1}$$

To avoid the assumption of unbiasedness, consistency, and efficiency, which could be a problem in linear models, two different models can be applied in panel data; the fixed-effects model, and the random-effects model. Which model to apply depends on if any of the variables used are correlated or not (Verbeek 2004). A fixed-effects model is defined in equation (2), where β is constant for all *i* and *t*, except for the intercept, α. When β is constant, the change in *x* is the same for all *i* and *t*. The model is constant since it is assumed that the individual-specific effect is correlated with at least one independent variable. Any behavior that is specific to the individual is captured in the intercept term α.

$$y_{it} = \alpha_i + x'_{it}\,\beta + \varepsilon_{it} \tag{2}$$

A random-effects model is defined in equation (3), where μ is the intercept term, and α and ε are the error terms. α is individual specific and random, and does not vary over time, and ε is a remainder variable that is uncorrelated with time. Variables affecting the dependent variable, but not included in the model, can be captured in a random error term (Verbeek 2004).

$$y_{it} = \mu_i + x'_{it}\,\beta + \alpha_i + \varepsilon_{it} \tag{3}$$

To determine the appropriate model to use, the Hausman test can be applied, which consists of a null hypothesis stating that x'_{it} and α_i are not correlated. During the test, the estimators are compared where one estimator is consistent under both the null hypothesis and the alternative hypothesis, and the other estimator is consistent and usually also efficient under the null hypothesis. If the null hypothesis cannot be rejected, a random-effects model should be applied; otherwise, a fixed-effects model should be applied (Verbeek 2004). The Hausman test I performed for this study got a p-value lower than 0.05, which means that the p-value is statistically significant at a 95 percent significance level. I should, therefore, reject the null hypothesis and apply the fixed-effects model.

5.2 Model

To analyze the effect of environmental policies on CO_2 emissions, 33 countries are studied over the years 1990 and 2014. Calculations are made in the program Stata. The regression used for this study can be seen in equation (4). In the first set of regressions, gasoline and diesel prices, and fossil fuel consumption is excluded. In the second set is fossil fuel consumption excluded, and in the third set of regressions, all variables are included. A fixed-effects model is used, as well as individual (α_i) and year (α_t) fixed-effects to hold any changes constant. Fuel prices are not fixed since I want to examine if the change in prices changes the CO_2 emissions, since the EPS index only captures the tax and not the price. All variables that are not in percentage already are logged to be able to interpret the changes in percentage. To control for any heteroskedasticity, robust standard errors are used.

$$ln\, CO2_{it} = \alpha_0 + \beta_1 EPS_{it} + \beta_2\, urbanpopulation_{it} + \beta_3 ln\, GDP_{it} + \beta_4\, GDP2_{it} + \beta_5 fossilfuel_{it} + \beta_6\, gasolineprice_{it} + \beta_7\, dieselprice_{it} + \alpha_i + \alpha_t + \varepsilon_{it} \quad (4)$$

To answer the research question, the coefficient β_1 is of the main interest in this study since it measures the effect of environmental policy stringency on CO_2 emissions. To find out what factors play the most important part in CO_2 emissions, the other coefficients will be of interest.

Eight regressions are made in this study. The first two regressions are made without any dummy variables and include all countries, measured in both CO_2 emissions per capita and total CO_2 emissions annually. The following four regressions are made with dummy variables for OECD countries and non-OECD countries, also measured in both CO_2 emissions per capita and total CO_2 emissions annually. The final two regressions are made with dummy variables for income; low and high-income countries, measured in CO_2 emissions per capita. β_3 is the coefficient for GDP, and β_4 is the coefficient for GDP squared. If β_4 is significant, the marginal effect of GDP is not constant. If β_3 is positive and β_4 is negative, and they both are significant, the effect is not constant, which supports the Environmental Kuznets Curve (EKC). The other variables are included as control variables to avoid omitted variable bias.

5.3 Limitations

It is common for some missing data in the empirical data set. Since panel data observes individuals over time, it is common that some data are missing, which can lead to an unbalanced data set. It is possible to exclude individuals with missing data from the panel data and only use a balanced sub-panel, but this is inefficient because data that might have an impact on the result could be excluded. It is, therefore, more efficient to include all individuals with missing data (Verbeek 2004). The data set in this study is strongly balanced, even if some data are missing. However, no countries are excluded, as Verbeek (2004) suggests.

Omitted variable bias can occur if a variable is unobserved and is correlated with variables included in the model. This means that the exogeneity assumption is not valid (Verbeek 2004). Panel data propose that individuals are heterogeneous. However, omitted variables varying over time can still exist but are smaller than in cross-sectional data (Baltagi 2005; Wooldridge 2002). Multiple control variables are included in this study; however, it is difficult to know if there are any other unobserved variables correlated with the variables in the model.

A cluster analysis could be used to divide individuals into groups, clusters, which share characteristics. The characteristics within the cluster should be related to each other and not as similar to the other clusters. Classifying the individuals could make it easier to find patterns that have an impact on an observed variable (Tan, Steinbach, Karpatne, Kumar 2018). Including clusters in the regressions of this study could give better results and interpretations; however, this is not done.

6 Results

In this section, I show the results on how varying stringency of environmental policies affect CO_2 emissions, and what factors play the most important part. The results from all the regressions can be seen in Tables 2, 3, and 4. Table 2 and Table 3 can be seen in Appendix 3 and 4. Table 2 shows the regression results when excluding the variables gasoline price, diesel price, and fossil fuel consumption. Table 3 shows the regression results when excluding the variable fossil fuel consumption. Table 4 can be seen below and shows the regression results including all variables. The explanations below are made for the regression results in Table 4.

In Table 4 below, in regression 1, the regression results show how the different variables are affecting CO_2 emissions per capita for all countries. The coefficient for the EPS index is -1.8, implying that CO_2 emissions decrease by 1.8 percent if the EPS index increases by 1 unit. However, this is insignificant. The coefficients for the urban population, GDP per capita, and fossil fuel consumption are positive and significant. If the urban population increases by 1 percent, CO_2 emissions per capita will increase by 1.4 percent. If GDP per capita increases by 1 percent, CO_2 emissions per capita will increase by 31.4 percent, and if fossil fuel consumption increases by 1 percent, CO_2 emissions per capita will increase by 2.1 percent. The coefficient for the gasoline price is negative and significant, which means that CO_2 emissions decrease by 31.6 percent if the gasoline price increases by 1 percent. The coefficient for diesel price is positive, increasing CO_2 emissions by 19 percent if diesel price increases by 1 percent. The constant is -3.603, which means that the expected value of the dependent variable will take this value if all the independent variables are zero.

In regression 2, the regression results show how the different variables are affecting total CO_2 emissions annually for all countries. The coefficient for the EPS index is negative but insignificant. Once again, the coefficients for the urban population, GDP, fossil fuel consumption, and diesel price are positive and significant. The coefficient for the gasoline price is negative and significant.

In regression 3, the regression results show how the different variables are affecting CO_2 emissions per capita for OECD countries. The coefficient for the EPS index is negative and insignificant. The urban population is insignificant as well. The coefficients for GDP per capita, fossil fuel consumption, and diesel prices are positive and significant, while a gasoline price is negative and significant. Regression results for OECD countries in total annual CO_2 emissions show the same significance and can be seen in regression 4.

In regression 5, the regression results show how the different variables are affecting CO_2 emissions per capita for non-OECD countries. The coefficient for the EPS index is positive and insignificant. The coefficients for the urban population, GDP per capita, and fossil fuel consumption are positive and significant. The gasoline price is negative and significant, while the diesel price is insignificant. Regression results for non-OECD countries in total annual CO_2 emissions are slightly different, as can be seen in regression 6. The coefficient for the EPS index is negative and insignificant, and GDP is insignificant as well. The urban population, fossil fuel consumption, and diesel price are positive and significant, while the gasoline price is negative and significant.

In regression 7, the regression results show how the different variables are affecting CO_2 emissions per capita in high-income countries. The coefficient for the EPS index is negative and insignificant, while the coefficients for GDP per capita, fossil fuel consumption, and diesel price are positive and significant. The gasoline price is negative and significant.

In regression 8, the regression results show how the different variables are affecting CO_2 emissions per capita in low-income countries. The coefficient for the EPS index is negative and insignificant, and the coefficients for the urban population, GDP per capita, fossil fuel consumption, and diesel price are positive and significant. The gasoline price is negative and significant.

Table 4: Regression results, all variables

	(1) **All countries CO_2 per capita**	**(2)** **All countries CO_2 annually**	**(3)** **OECD countries CO_2 per capita**	**(4)** **OECD countries CO_2 annually**	**(5)** **Non-OECD countries CO_2 per capita**	**(6)** **Non-OECD countries CO_2 annually**	**(7)** **High-income countries CO_2 per capita**	**(8)** **Low-income countries CO_2 per capita**
EPS index	-0.018 (0.396)	-0.026 (0.283)	-0.016 (0.277)	-0.017 (0.296)	0.006 (0.828)	-0.009 (0.881)	-0.016 (0.423)	-0.016 (0.423)
Urban population	0.014 ** (0.037)	0.015 ** (0.027)	-0.002 (0.722)	-0.002 (0.801)	0.025 ** (0.014)	0.026 *** (0.000)	0.014 * (0.037)	0.014 ** (0.037)
GDP per capita	0.314 *** (0.000)		0.230 *** (0.000)		0.278 ** (0.046)		0.328 *** (0.000)	0.328 *** (0.000)
GDP per capita squared	0.000 (0.545)		0.000 (0.579)		0.000 (0.453)		0.000 (0.461)	0.000 (0.461)

GDP annually		0.322 *** (0.000)		0.277 *** (0.001)		0.108 (0.377)		
GDP annually squared		0.000 (0.580)		0.000 (0.795)		0.000 (0.239)		
Fossil fuel consumption	0.021 *** (0.000)	0.023 *** (0.000)	0.021 *** (0.000)	0.024 *** (0.000)	0.028 *** (0.003)	0.039 *** (0.001)	0.021 *** (0.000)	0.021 *** (0.000)
Gasoline price	-0.316 *** (0.002)	-0.338 *** (0.001)	-0.482 *** (0.002)	-0.456 *** (0.002)	-0.286 ** (0.026)	-0.339 *** (0.007)	-0.321 *** (0.001)	-0.321 *** (0.001)
Diesel price	0.190 * (0.080)	0.213 ** (0.044)	0.351 ** (0.015)	0.320 ** (0.034)	0.087 (0.232)	0.198 ** (0.017)	0.192 * (0.073)	0.192 * (0.073)
Constant	-3.603 *** (0.000)	7.782 *** (0.000)	-1.957 ** (0.025)	9.489 *** (0.000)	-4.277 *** (0.004)	13.404 *** (0.005)	-3.656 *** (0.000)	-3.682 *** (0.000)

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

Source: Own calculations from Stata

7 Discussion

In this study, I explore whether or not the varying stringency of environmental policies affects CO_2 emissions.

The regression results from the three different sets of regressions show similar coefficients and significance. The results are robust to varying specifications. Comparing estimations of the first and second regression, with and without fuel prices, the estimations have a similar magnitude. This suggests that the fuel prices for gasoline and diesel are not correlated with the EPS index. In the third regression, the estimations have a similar magnitude as the first two regressions, which suggests that fossil fuel consumption is not correlated with the CO_2 emissions. By adding the variables fossil fuel consumption, and fuel prices for gasoline and diesel, the estimations with similar magnitude suggest that it does not influence the results.

The results imply that environmental policies are insignificant for all countries included, OECD countries, non-OECD countries, and different income countries. The stringency of environmental policies has, therefore, a limited effect on CO_2 emissions, and further conclusions cannot be made. One of the potential explanations is that the EPS index captures many types of regulations and not only the ones associated with CO_2 emissions. According to Bruvoll and Larsen (2004), a possible reason for the insignificant results can be due to tax exemptions, where several countries in this study are likely to be exempted from carbon taxation. The findings of this study are in line with several previous studies, for example, Lin and Li (2011), Stanislav and Speck (2018), and Bohlin (1998), which study the effect of a carbon tax on emissions in different countries and found that a carbon tax was insignificant.

The study also found that the stringency of environmental policies does not seem to have different effects on CO_2 emissions in countries with different income levels. The EPS index is negatively associated with the CO_2 emissions in all different income countries; however, this is not significant. Another result of this study showed that the marginal effect of GDP was negative but not significant, which means that the marginal effect of GDP was constant over time. This implies that emissions are not decreasing as countries are being industrialized and more prosperous. Therefore, no inverted U-shaped curve that supports the Environmental Kuznets Curve (EKC) was found in this study. The results from previous research on the EKC resulted in varying outcomes, and this study is in line with Al-Mulali, Saboori, Ozturk (2015) that did not find support for the EKC. It can also be observed in Figure 3, that no clear relationship seems to be found between income and CO_2 emissions. From observing Figure 4, countries with lower GDP seem to have relatively higher EPS indexes than countries with higher GDP. If the EPS index is relatively low compared to GDP, the effect is, therefore, too small to have a significant decrease in CO_2 emissions. However, higher-income countries should, according to Ritchie and Roser (2019), have better environmental resources to make a significant impact on CO_2 emissions. Ritchie and Roser (2019) argue that there is a strong relationship between high-income countries and higher emissions. However, they also point out that high-income European countries emit less than other high-income countries. This is due to increased energy and technological efficiency and electricity produced from renewable and nuclear energy (Ritchie & Roser 2019). According to the Swedish Government (2020), environmental policies such as carbon tax creates incentives to develop new technologies and increase the use of renewable energy. Since the reductions of CO_2 emissions were not significant in this study, the findings of this study are in line with Stanislav and Speck (2018), which found that renewable energy sources did not have a significant reducing effect on CO_2 emissions.

A variable that was negative and significant in all regressions of this study was gasoline price, which showed that a higher gasoline price played an important part in decreasing CO_2 emissions. In contrast, diesel price was positive and significant for some regressions and insignificant in others. One explanation for this can be that the diesel prices are not high enough to make a significant difference. The demand for fuel for cars tends to be very inelastic, meaning that increasing prices in fuel have a small effect on demand (Bruvoll & Larsen 2004; Morris 2014). Another explanation can be that diesel engines are more fuel-efficient than gasoline engines. In other words, diesel contains more energy than gasoline, which makes diesel vehicles able to travel 20 percent to 35 percent farther than gasoline vehicles (Fuel Economy 2019). Therefore, increasing gasoline prices may cause people to switch to diesel engines, which can explain the increasing CO_2 emissions for diesel vehicles. The results of this study are both in line and differ from Stanislav and Speck's (2018) study, which found that a higher oil price was important to reduce CO_2 emissions, which the results of this study showed for gasoline prices, but not for diesel prices.

This study also found that fossil fuel consumption was positive and significant in all regressions, which showed that fossil fuel consumption played an important part in increasing CO_2 emissions. This could mean that the carbon taxes on the carbon content in fossil fuels are too low to make a significant reduction in CO_2 emissions. As mentioned above, the prices for fuels are inelastic, and price changes have, therefore, small effects on demand (Bruvoll & Larsen 2004; Morris 2014). Another reason could be as Bruvoll and Larsen (2004) argue that the small effect is due to carbon tax exemptions. Many of the industry's largest emitters of carbon dioxide are exempted from tax (Bruvoll & Larsen 2004), which may affect the results. The findings in this study are in line with Bruvoll and Larsen (2004), which studied a carbon tax and concluded that it had a limited effect on CO_2 emissions on fossil fuel.

Another finding in this study showed that the variables in the regressions had different effects on CO_2 emissions per capita and total annual CO_2 emissions. The results for non-OECD countries showed a difference in significance in multiple variables. However, the regressions for non-OECD countries included only six countries and the data set was therefore small, which may affect the results.

8 Conclusion

The purpose of this study is to determine the relationship between varying stringency of environmental regulations and CO_2 emissions. This study uses the EPS index to evaluate if different levels of environmental policy stringency have an impact on CO_2 emissions in different countries. Furthermore, this study also examines which variables play the most important part in CO_2 emissions.

The main finding of this study is that more stringent environmental policies do not have a significant effect on CO_2 emissions. However, fossil fuel consumption and gasoline price turned out to be the most important. Increased fossil fuel consumption has a significant impact in increasing CO_2 emissions, while an increasing gasoline price has a significant impact in reducing CO_2 emissions.

These findings contribute to previous research and an understanding of the relationship between the stringency of environmental policies and CO_2 emissions across countries. Furthermore, they contribute to an understanding of what factors play a crucial part in CO_2 emissions. However, this study is limited due to the lack of data availability. Further research could include geographically diverse and more income varying countries, as well as different control variables such as crude oil, electricity and heat prices, industrialization, and renewable energy use.

If the results of this study are correct, it implies that there is no significant relationship between the stringency of environmental policies and CO_2 emissions, no matter if the country is part of the OECD or not, or what income they have. Furthermore, fossil fuel consumption and gasoline prices are significant and are therefore associated with CO_2 emissions, which means that policymakers should focus on reducing fossil fuel consumption, and one step towards that could be higher gasoline prices.

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Appendix 1

List of countries

OECD countries		
Australia	Greece	Portugal
Austria	Hungary	Slovak Republic
Belgium	Ireland	Slovenia
Canada	Italy	Spain
Czech Republic	Japan	Sweden
Denmark	Korea	Switzerland
Finland	Netherlands	Turkey
France	Norway	United Kingdom
Germany	Poland	United States
Non-OECD countries		
Brazil	India	Russia
China	Indonesia	South Africa

Appendix 2

Variable description

Variable	**Description**
EPS index	Environmental policy stringency index
CO_2 emissions per capita	CO_2 emissions per capita in metric tons
CO_2 emissions annually	Total annual CO_2 emissions in metric tons
Urban population	Urban population in percentage of total population
GDP	GDP in current US dollars
GDP 2	GDP in current US dollars squared
GDP per capita	GDP per capita in current US dollars
GDP per capita 2	GDP per capita in current US dollars squared
Fossil fuel consumption	Fossil fuel consumption in percentage of total consumption
Gasoline price	Gasoline pump price per liter in current US dollars
Diesel price	Diesel pump price per liter in current US dollars

Appendix 3

Table 2: Regression results, excluding gasoline price, diesel price and fossil fuel consumption

	(1) All countries CO_2 per capita	(2) All countries CO_2 annually	(3) OECD countries CO_2 per capita	(4) OECD countries CO_2 annually	(5) Non-OECD countries CO_2 per capita	(6) Non-OECD countries CO_2 annually	(7) High-income countries CO_2 per capita	(8) Low-income countries CO_2 per capita
EPS index	-0.025	-0.032	0.017	0.019	0.024	0.126	-0.022	-0.022
	(0.361)	(0.332)	(0.423)	(0.434)	(0.580)	(0.430)	(0.377)	(0.377)
Urban population	0.027 ***	0.029 ***	0.018 **	0.020 **	0.020	0.032	0.025 ***	0.025 ***
	(0.000)	(0.000)	(0.049)	(0.032)	(0.203)	(0.159)	(0.001)	(0.001)
GDP per capita	0.276 ***		0.152 *		0.278 *		0.305 ***	0.305 ***
	(0.000)		(0.063)		(0.062)		(0.000)	(0.000)
GDP per capita squared	0.000		0.000		0.000		0.000	0.000
	(0.787)		(0.630)		(0.121)		(0.609)	(0.609)
GDP annually		0.320 ***		0.231 **		0.146		
		(0.000)		(0.024)		(0.325)		
GDP annually squared		0.000		0.000		0.000		
		(0.819)		(0.648)		(0.601)		
Constant	-2.426 ***	8.750 ***	-0.630	11.306 ***	-1.986 **	14.736 ***	-2.533 ***	-2.601 ***

	(0.000)	(0.000)	(0.600)	(0.001)	(0.010)	(0.004)	(0.000)	(0.000)

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

Source: Own calculations from Stata

Appendix 4

Table 3: Regression results, excluding fossil fuel consumption

	(1) All countries CO_2 per capita	(2) All countries CO_2 annually	(3) OECD countries CO_2 per capita	(4) OECD countries CO_2 annually	(5) Non-OECD countries CO_2 per capita	(6) Non-OECD countries CO_2 annually	(7) High-income countries CO_2 per capita	(8) Low-income countries CO_2 per capita
EPS index	-0.026	-0.028	-0.002	0.001	0.012	0.124	-0.023	-0.023
	(0.248)	(0.295)	(0.916)	(0.966)	(0.832)	(0.385)	(0.288)	(0.288)
Urban population	0.029 ***	0.030 ***	0.015	0.018 *	0.024 *	0.037 *	0.027 ***	0.027 ***
	(0.000)	(0.000)	(0.100)	(0.082)	(0.094)	(0.089)	(0.000)	(0.000)
GDP per capita	0.403 ***		0.281 ***		0.406 **		0.434 ***	0.434 ***
	(0.000)		(0.003)		(0.026)		(0.000)	(0.000)
GDP per capita squared	0.000		0.000		0.000**		0.000	0.000
	(0.730)		(0.145)		(0.048)		(0.992)	(0.992)
GDP annually		0.466 ***		0.398 ***		0.220		
		(0.000)		(0.000)		(0.181)		
GDP annually squared		0.000		0.000		0.000		
		(0.233)		(0.177)		(0.679)		
Gasoline price	-0.364 ***	-0.394 ***	-0.467 **	-0.445 **	-0.303 *	-0.373 *	-0.374 ***	-0.374 ***
	(0.001)	(0.001)	(0.012)	(0.015)	(0.074)	(0.083)	(0.001)	(0.001)

Diesel price	0.200	0.193	0.337	0.238	0.043	0.167	0.204	0.204
	*	*	**				**	**
	(0.059)	(0.074)	(0.032)	(0.179)	(0.727)	(0.302)	(0.047)	(0.047)
Constant	-3.869	5.194	-1.942	6.757	-3.347	12.361	-3.987	-4.049
	***	***	**	**	**	**	***	***
	(0.000)	(0.004)	(0.121)	(0.035)	(0.019)	(0.016)	(0.000)	(0.000)

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

Source: Own calculations from Stata