

**MASTER**

ECONOMICS

**Master's Final Work**

DISSERTATION

DOES FISCAL POLICY AFFECT THE ENVIRONMENT?

AN EMPIRICAL EXPLORATION

MADALENA COSTA SANTOS IVO DE CARVALHO

OCTOBER 2022



LISBON  
SCHOOL OF  
ECONOMICS &  
MANAGEMENT  
UNIVERSIDADE DE LISBOA

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PROF. DOUTOR JOÃO OOM DE SOUSA TOVAR JALLES

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**Abstract**

Substantial uncertainty exists about the effectiveness of fiscal policy in reducing the negative consequences associated to climate change. The concern about environmental sustainability has increased significantly since the Twenty-First session of the Conference of the Parties (COP 21), and literature have been focused in studying the impact of government expenditure or fiscal policy on carbon dioxide emissions (Zhang, 2021; Ike et al., 2020). Incorporating evidence from the literature this study tests the effectiveness of the fiscal policy, calculated by Principal component analysis methodology, measured by tax revenues and Government expense, on environmental degradation. Annual data from 1990 to 2021 has been used and in addition gross domestic product, energy consumption, and fiscal policy were selected as independent variables for the ARDL (Autoregressive Distributed Lag) model, to test the fiscal policy on the independent variable, greenhouse emissions. This work is based on a sample of 29 countries, with different incomes and different with different degrees level of development. Results revealed that fiscal policy is effective for most of the countries selected in the sample, showing long-run inverse trend relationship between fiscal policy and Greenhouse emissions. From the total sample, only seven countries showed no long-run relationship between fiscal policy and the environment, concluding that environmental tax reform is needed. From the overall results in this study, was concluded that fiscal policy is an effective instrument and should be applied to the countries, to achieve global targets for the environment, mitigation of greenhouse emissions, although some reforms are needed for specific countries with no cointegration.

**Keywords:** Greenhouse emissions; Fiscal Policy Index; Cointegration; Tax reform; ARDL model; Principal Component Analysis

**Resumo**

O efeito da política orçamental na minimização das consequências nefastas associadas às alterações climáticas é incerto. A preocupação com a sustentabilidade ambiental aumentou significativamente desde a 21ª sessão da Conferência das Partes e a literatura tem-se concentrado no estudo do impacto das despesas governamentais ou da política orçamental sobre as emissões de dióxido de carbono (Zhang, Jihuan., 2021; Ike et al., 2020). Com base na literatura, este estudo testa a eficácia da política orçamental, calculada pela metodologia de análise de componentes principais, medida pelas receitas fiscais e despesas governamentais, sobre a degradação ambiental. Foram utilizados dados anuais de 1990 a 2021 e, o produto interno bruto, o consumo de energia e a política orçamental foram seleccionados como variáveis independentes para o modelo Autoregressive Distributed Lag, a fim de testar a política orçamental sobre a variável independente, as emissões de gases com efeito de estufa. Este trabalho é baseado numa amostra de 29 países, com diferentes rendimentos e diferentes níveis de desenvolvimento. Os resultados revelaram que a política orçamental apresenta uma relação de cointegração para a maioria dos países mostrando uma relação com tendência inversa de longo prazo entre a política orçamental e as emissões de gases com efeito de estufa. Da amostra total, apenas sete países não mostraram qualquer relação de longo prazo, concluindo que é necessária uma reforma orçamental ambiental. Dos resultados globais deste estudo, concluiu-se que a política orçamental é um instrumento com influencia nos gases efeito de estufa e deve ser aplicada para atingir metas globais para o ambiente, mitigação dos efeitos dos gases efeito de estufa, embora sejam necessárias algumas reformas para países específicos sem cointegração.

**Palavras-Chave:** Emissões de gases efeitos de estufa; Índice de política orçamental; Cointegração; Reforma fiscal; modelo ARDL, Análise de Componentes Principais

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## **Glossary**

**NOAA**- National Oceanic and Atmospheric Administration

**GHG**- Greenhouse emissions

**CO<sub>2</sub>** - Carbon Dioxide

**CH<sub>4</sub>**-Methane

**COP 21** - Twenty-First session of the Conference of the Parties

**COP 26** - Twenty-Sixth session of the Conference of the Parties

**Gt**- Gigatons

**GDP**- Gross Domestic Product

**CREA**- Center for Research on Energy and Clean Air

**SO<sub>2</sub>**- Sulfur Dioxide

**EKC** - Environmental Kuznets Curve

**GMM** - Generalized Method of Moments

**DOLS** - Dynamic Ordinary Least Square

**FMOLS**- Fully Modified Ordinary Least Square

**CCPI** - Climate change Performance Index

**IMF** - The International Monetary Fund

**N<sub>2</sub>O**-nitrous oxide

**H<sub>2</sub>O**- water vapor

**F-gases**- Fluorinated gases

**PCA**- Principal Component Analysis

**FPI**- Fiscal Policy Index

**EC**- Energy Consumption

**ADF** - Augmented Dickey-Fuller

**ARDL**- Autoregressive Distributed Lag Model

**VAR**- Autoregression Model

**ECM** - Error Correction Model

**AIC**- Akaike Information Criteria

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## 1. Introduction

Global warming - the unusual and gradual heating of Earth's surface - is increasing quickly and the path to keep the Earth safe is challenging and demanding. Global temperature is increasing every year, 0.08° Celsius, and 2021 was considered one of the warmest years, according to National Oceanic and Atmospheric Administration (NOAA) temperature data. Global warming is a long-term consequence of human overuse of fossil fuels as energy resources. The combustion of fossil fuels increases the concentration of Greenhouse Gases (GHGs) in the atmosphere, such as carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). Consequently, the pressure on Earth is increasing, which can be seen by the rising sea levels or the higher frequency of natural disasters (Jaumotte et al., 2021).

The concern about environmental sustainability has increased significantly since the Twenty-First session of the Conference of the Parties (COP 21), where 195 parties adopted the Paris agreement<sup>1</sup>. This agreement, a landmark in mitigating climate change, limited global warming increase to 2 degrees Celsius. More recently, during the Twenty-Sixth session of the Conference of the Parties (COP 26) in 2021, the European Union countries took a step forward in climate change combat and agreed to achieve zero emissions by 2050. However, in 2021, CO<sub>2</sub> global emissions reached the highest annual value, registering 36.3 gigatons (Gt). Furthermore, after the Coronavirus disease (COVID-19) pandemic crisis, the world saw the energy sector's recovery aggravated by climate changes, given the higher intensity of coal combustion and, consequently, a higher level of GHG emissions. Therefore, countries must rethink their behavior and change it to pursue a sustainable path, reducing its impacts and damage on the global environment.

The green fiscal policy is a standard instrument that Governments use to achieve the environmental goals established in the different sectors. As discussed during the United Nations Conference in 1992, one of the most significant advantages of environmental charges is that they can correct price distortions by adding the cost of pollution and others to the prices. However, fiscal policies adopted in the past years were insufficient to achieve the necessary levels (Jaumotte et al., 2021).

After the COVID-19 pandemic crisis, which was a period of temporary reduction of emissions (Quéré et al., 2020), it is essential to review the policies to ensure that the

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<sup>1</sup> Paris Agreement - United Nations Framework Convention on Climate Change - EUR-Lex (europa.eu)

established goals for global warming are achieved. In this framework, and considering the previous works published in this field, this work intends to test the fiscal policy's effectiveness through the long-term relationship between policies and ecological degradation, measured by Greenhouse emissions. By using the Principal Component analysis methodology, it was defined the fiscal policy index which will be the core independent variable in this study. Using this variable, it will be possible to observe how the two main components of a fiscal policy, tax revenues, and government expenditure, may affect the reduction of GHG emissions.

The contribution of this study to the literature is twofold, being the main objective to verify whether fiscal policies impact environmental degradation, measured through greenhouse gas emissions variations. Secondly, through Gross Domestic Product (GDP), energy consumption, and fiscal policy, it aims to understand the results especially the country's conjecture and inform policymakers.

The remainder of the thesis is organized as follows. Section 2 discusses the literature review with a focus on the relationship between fiscal policy and its impact on the environment degradation. Section 3 explains the data used in this study and section 4 discusses the empirical methodology used to answer the main proposed research question. Empirical results are then discussed in Section 5. Conclusions will be discussed in section 6 will then analyze limitations and future work directions.

## 2. Literature Review

The tentative to foster economic growth and development and simultaneously ensure the preservation of natural assets should be a focus when facing climate change. Nowadays, climate crisis is a worrisome reality, and each country has its responsibility to design and create a path toward a greener economy. The consumption of fossil fuel and economic growth are connected, as argued by the latest study performed by Greenpeace Southeast Asia and the Center for Research on Energy and Clean Air (CREA), which found that air pollution from fossil fuels cost 3.3% of global GDP. This phenomenon reinforces the urgency to minimize and monitor GHG emissions (Coady et al., 2019). From a chemical perspective, most studies focus on Sulfur Dioxide (SO<sub>2</sub>) and CO<sub>2</sub> as the primary sources of pollution. SO<sub>2</sub> is the chemical substance associated with industrial and electricity generator activities, and CO<sub>2</sub> mainly to transport activities.

Concerns regarding the possibility of reducing the impact of general economic activity on the environment have increased both the practitioners and academics attention (Calavera et al.2022). However, most empirical past studies focused on economic growth and environmental sustainability and are typically connected with the Environmental Kuznets Curve (EKC) (Kuznets, 1955). This theory claims an inverted relationship between environmental deterioration and income per capita.

Researchers had conducted general approaches and including new factors to study the correlation between government spending, fiscal policies, and economic growth. Most studies tend to focus on case studies analysis of specific countries (Katircioglu et al., 2018; Zhang, Jihuan, 2021). Ramon et al. (2011) studied the impact of different fiscal spending programs on reducing air and water pollutants. Ike et al. (2020) and Zhang, Jihuan, (2021) focused on the correlation between government expenditure, energy consumption, and CO<sub>2</sub> emissions. In their studies, the authors assessed whether a strong correlation between environmental sustainability and energy usage exists. From another perspective, through econometrics estimations, several studies showed that government expenditures across different sectors, such as education, health and social transfers, or research and development, correlate with environmental quality, leading to its increase.

From the literature on this subject, the works of Lopez et al. (2011), Halkos & Paizano (2013), and Katircioglu et al. (2018) brought new studies and relevant contributions to the literature. Lopez et al. (2011) studied the relationship between Government expenditure on public goods and the environment, specifically the pollution generated in

different sectors. The authors distinguished between public and private goods and argued that public goods reduce the harmful effects of the economic market and private goods are not relevant to eliminate the market flaws. Even if the environmental fiscal policy remains unchanged, the authors showed that the change in the decomposition of government spending would have an impact in environmental degradation. The authors perform an econometric analysis through data collected from more than 38 countries for air pollution and water quality. The authors developed a new powerful model and brought new insights by showing the effects of level and composition of fiscal spending on the environmental degradation, that can be reflected in different policies focused on public goods expansions applied by many countries, such as United states.

Halkos et al. (2013) studied the relationship between fiscal policy and pollution, by taking in consideration a new perspective, the dynamic nature of this relationship. The authors collected data from 77 countries and gathered more than 1617 observations per variable to conduct a Generalized Method of Moments (GMM) analysis and assess the direct and indirect effects of fiscal spending on environmental pollution. The authors found that cutting government expenditure in countries with high levels of income will improve the environment. By combining the study of Lopez et al. (2011) and this study with the new vision of the dynamic relationship, was showed that cutting spending items that lead to market failures will be favorable for the environmental degradation.

Katircioglu et al. (2018) explored the connection between fiscal policy and CO<sub>2</sub> emissions by testing EKC. The authors used Turkey as a case study and analyzed it from 1963 to 2013. By applying a time series analysis, the results showed that through energy consumption and real income growth in the long term, a relationship is observed between fiscal policy and CO<sub>2</sub> emissions. However, from statistical results, the authors observed that the fiscal policy had no impact on higher levels of CO<sub>2</sub> emissions. This study had introduced a new important research in the energy sector economic literature not only for the main results of the study but also by showing that a improvement in the fiscal policy by the Turkish Authorities towards public and private sector, would lead to a downward sloping in the Environmental Kuznets Curve, and would be a step forward to combat environmental degradation in the country.

Akbar et al. (2020) studied the dynamic role of fiscal policy in energy efficiency and CO<sub>2</sub> emission applied to Asia's belt and road region. By applying the dynamic ordinary least squares estimator (DOLS) and fully modified OLS (FMOLS), the authors were able to

conclude that the CO<sub>2</sub> emissions converge to a long-run equilibrium once they are impacted by the fiscal policy index (determined by the Principal Component Analysis methodology) and energy efficiency. Moreover, fiscal policy and energy efficiency have a negative relationship in the long run in the region of study.

All in all, different studies studied and tested the impact of government expenditure or fiscal policy on CO<sub>2</sub> emissions, but neither tested the fiscal policy's effectiveness on different countries for comparison by the GHG variable to the model. This is the current gap that this master thesis intends to fill. One way of doing this, as suggested by the literature reviewed, is that the most efficient policy to follow is reducing public spending on the goods that lead to market inefficiency, leading to significant benefits, especially when analyzing the case for CO<sub>2</sub>.

### 3. Data

The main goal of this thesis is to empirically assess the effectiveness of fiscal policy in affecting environmental degradation, through the study of the long-term relationship between these variables.

The sample of countries chosen was dictated by the variable Climate change Performance Index (CCPI) (Burck et al., 2022). The index is based on a range of countries and a combination of different indices and in a combination of surveys performed.

It was decided to use this sample to verify the effectiveness of fiscal policy in all countries and whether it has a relevant impact on environmental degradation.

As such, the panel dataset comprises 29 countries from 1990 to 2021. Moreover, the sample selected was based on the Climate Change Performance Index (CCPI) ranking, of which the countries with relevant data were selected taking into consideration the relevance of its economy by geography and to study the different impact of fiscal policy in development countries and developing countries.

This selection allowed us to understand how the key players by region reveal or not a relation between its economy and how they can influence the reduction of GHG emissions depending on crucial aspects that characterize each area.

In the selected sample, 20 countries belong to the European continent, 3 to Asia, 1 to Oceania, 2 to America, 1 to Africa, and 2 to Asia and Europe (Russia and Turkey). It is worth noting the inclusion of Indonesia, USA, and Russia, three of the five countries that have been polluted the most since the industrial revolution (United States of America, Russia, Brazil, and Indonesia), based on the last information released from Carbon Brief, 2021.

This paper aims to study the effectiveness of Fiscal Policy in the case of total GHG, by analyzing the long-run impact of fiscal policy on GHG. The International Monetary Fund (IMF) defines fiscal policy as “the use of government spending and taxation to influence the economy.”

For this paper, we apply an econometric analysis to test the effectiveness of Fiscal Policy on the environment. Considering previous literature, the emissions level of CO<sub>2</sub> have been used as the indicator variable for environmental degradation (Halkos et al., 2013; Arkbar et al., 2020).

For the current estimation, we will use as the indicator variable the GHG, the main gases responsible for the degradation of the environment through the greenhouse effect. The major components are CO<sub>2</sub>, CH<sub>4</sub>, nitrous oxide (N<sub>2</sub>O), water vapor (H<sub>2</sub>O), and fluorinated gases (F-gases).

In resume for the specification of the model used, the following variables were chosen: Total GHG (kt of CO<sub>2</sub> emissions), Energy consumption (kg of oil equivalent per capita), GDP (Constant LCU), and the Fiscal Policy index, expressed by tax revenue (LCU) and government expense (LCU).

The data was defined through annual variables from 1990 to 2021, and table 1 displays the variables' definition and the sources for the respective data. The descriptive analysis of the data applied in this study is shown in Table 2.

**Table I** : Variables description

| <b>Variables</b> | <b>Definition</b>   | <b>Source</b>  |
|------------------|---|----------------|
| <b>GHG</b>       | Total greenhouse gas emissions (kt of CO <sub>2</sub> equivalent) | World Bank     |
| <b>EC</b>        | Energy use (kg of oil equivalent per capita)                      | IEA Statistics |
| <b>GDP</b>       | Gross Domestic Product<br>(Constant LCU)                          | World bank     |
| <b>FPI</b>       | government spending and tax revenue                               | World bank     |

Energy consumption was added to the model as an independent variable, based on the existing literature, since there is a positive relationship between environmental degradation and energy consumption, meaning that an increase in energy consumption will lead to an increase of CO<sub>2</sub> emissions in the long-run (Hossain & Sharif, 2012), and (Zhang & Jihuan, 2021). GDP was also added as an independent variable to the model, and based on the literature, was shown the evidence of a N shape relationship in the long run between GDP and Environment (Zhang, Jihuan., 2021).

To define the Fiscal Policy index (FPI) we apply the same approach as Ike et al., (2019), by using a Principal Component Analysis (PCA) (Person, 1901)<sup>2</sup> with two different inputs: government spending (constant LCU) and tax revenues (constant LCU).

For the estimation of Fiscal policy index, it was used government spending (constant LCU) and tax revenues (constant LCU) once the fiscal policy is an instrument used through government spending and taxation in order to influence the economy and promote a growth by reducing unstable conjectures.

<sup>2</sup> Principal component analysis is a technique used for analyzing large data sets containing big data sets and converting possibly correlated variables into a set of linearly uncorrelated variables.

Table II: Descriptive Analysis of the data

| Country/Variable | GHG (kt of CO2 equivalent) |           | EC (kg of oil equivalent per capita) |       | GDP (constant LCU) |                        | Tax revenue (LCU) |                       | Government spending (LCU) |                       |
|------------------|----------------------------|-----------|--------------------------------------|-------|--------------------|------------------------|-------------------|-----------------------|---------------------------|-----------------------|
| Australia        | Average                    | 568 895   | Average                              | 5 482 | Average            | 1 349 833 901 180      | Average           | 234 919 903 226       | Average                   | 199 819 500 000       |
|                  | Max                        | 668 340   | Max                                  | 5 965 | Max                | 2 054 742 484 811      | Max               | 455 762 000 000       | Max                       | 442 914 000 000       |
|                  | Min                        | 486 990   | Min                                  | 4 928 | Min                | 784 453 019 233        | Min               | 87 365 000 000        | Min                       | 70 257 000 000        |
| Austria          | Average                    | 80 452    | Average                              | 3 713 | Average            | 302 675 917 143        | Average           | 65 397 077 980        | Average                   | 51 914 560 750        |
|                  | Max                        | 90 350    | Max                                  | 4 086 | Max                | 371 150 923 076        | Max               | 101 604 620 000       | Max                       | 86 622 090 000        |
|                  | Min                        | 75 000    | Min                                  | 3 234 | Min                | 221 190 803 894        | Min               | 24 732 745 652        | Min                       | 24 725 305 000        |
| Belgium          | Average                    | 125 984   | Average                              | 5 279 | Average            | 361 786 305 274        | Average           | 84 122 365 385        | Average                   | 72 685 400 063        |
|                  | Max                        | 142 410   | Max                                  | 5 669 | Max                | 447 177 638 278        | Max               | 110 451 600 000       | Max                       | 120 237 900 000       |
|                  | Min                        | 106 510   | Min                                  | 4 688 | Min                | 268 729 492 560        | Min               | 53 932 400 000        | Min                       | 34 388 959 000        |
| Canada           | Average                    | 651 509   | Average                              | 7 973 | Average            | 1 739 389 849 200      | Average           | 184 154 419 355       | Average                   | 302 440 531 250       |
|                  | Max                        | 737 990   | Max                                  | 8 456 | Max                | 2 229 192 967 291      | Max               | 295 057 000 000       | Max                       | 539 328 000 000       |
|                  | Min                        | 536 290   | Min                                  | 7 517 | Min                | 1 158 666 042 912      | Min               | 98 150 000 000        | Min                       | 157 310 000 000       |
| Czech Republic   | Average                    | 139 184   | Average                              | 4 175 | Average            | 3 789 956 673 412      | Average           | 507 841 642 857       | Average                   | 658 065 088 625       |
|                  | Max                        | 181 960   | Max                                  | 4 797 | Max                | 5 324 933 414 974      | Max               | 855 333 000 000       | Max                       | 1 312 971 000 000     |
|                  | Min                        | 116 590   | Min                                  | 3 783 | Min                | 2 516 501 120 578      | Min               | 223 364 000 000       | Min                       | 160 092 373 000       |
| Denmark          | Average                    | 66 097    | Average                              | 3 517 | Average            | 1 801 369 601 838      | Average           | 511 594 290 323       | Average                   | 398 346 548 188       |
|                  | Max                        | 90 060    | Max                                  | 4 170 | Max                | 2 321 718 955 890      | Max               | 801 666 000 000       | Max                       | 608 686 080 000       |
|                  | Min                        | 43 200    | Min                                  | 2 817 | Min                | 1 313 212 270 575      | Min               | 254 311 000 000       | Min                       | 204 534 747 000       |
| Finland          | Average                    | 68 591    | Average                              | 6 312 | Average            | 190 744 654 011        | Average           | 34 253 633 256        | Average                   | 37 191 625 000        |
|                  | Max                        | 85 140    | Max                                  | 7 135 | Max                | 233 185 764 673        | Max               | 49 575 000 000        | Max                       | 60 913 000 000        |
|                  | Min                        | 51 480    | Min                                  | 5 381 | Min                | 130 165 260 498        | Min               | 19 215 134 222        | Min                       | 18 983 000 000        |
| France           | Average                    | 481 028   | Average                              | 4 033 | Average            | 1 941 232 367 179      | Average           | 386 831 823 147       | Average                   | 409 975 406 250       |
|                  | Max                        | 520 920   | Max                                  | 4 302 | Max                | 2 353 900 917 538      | Max               | 597 578 000 000       | Max                       | 603 524 000 000       |
|                  | Min                        | 414 040   | Min                                  | 3 659 | Min                | 1 497 295 530 363      | Min               | 197 373 913 229       | Min                       | 223 024 000 000       |
| Germany          | Average                    | 938 570   | Average                              | 4 075 | Average            | 2 683 272 174 660      | Average           | 270 756 454 838       | Average                   | 478 999 468 188       |
|                  | Max                        | 1 128 090 | Max                                  | 4 421 | Max                | 3 257 554 201 831      | Max               | 396 338 000 000       | Max                       | 801 341 000 000       |
|                  | Min                        | 749 710   | Min                                  | 3 779 | Min                | 2 090 205 479 860      | Min               | 143 903 099 963       | Min                       | 279 547 982 000       |
| Greece           | Average                    | 105 238   | Average                              | 2 399 | Average            | 181 594 937 702        | Average           | 37 666 299 068        | Average                   | 31 748 954 813        |
|                  | Max                        | 125 640   | Max                                  | 2 753 | Max                | 236 589 627 264        | Max               | 48 915 000 000        | Max                       | 55 366 872 000        |
|                  | Min                        | 78 500    | Min                                  | 2 091 | Min                | 140 168 561 488        | Min               | 6 886 074 835         | Min                       | 7 961 594 000         |
| Hungary          | Average                    | 68 757    | Average                              | 2 524 | Average            | 30 222 602 427 850     | Average           | 4 819 059 645 161     | Average                   | 4 867 353 301 194     |
|                  | Max                        | 89 100    | Max                                  | 2 774 | Max                | 41 396 302 691 096     | Max               | 11 072 511 000 000    | Max                       | 11 312 742 000 000    |
|                  | Min                        | 55 260    | Min                                  | 2 272 | Min                | 21 110 314 163 199     | Min               | 610 900 000 000       | Min                       | 647 229 428 000       |
| India            | Average                    | 2 132 260 | Average                              | 454   | Average            | 71 995 850 787 850     | Average           | 6 036 061 937 931     | Average                   | 7 771 997 925 065     |
|                  | Max                        | 3 394 870 | Max                                  | 637   | Max                | 150 649 396 001 387    | Max               | 22 712 540 000 000    | Max                       | 26 858 647 791 600    |
|                  | Min                        | 1 219 550 | Min                                  | 350   | Min                | 24 984 166 255 668     | Min               | 575 740 000 000       | Min                       | 650 167 577 470       |
| Indonesia        | Average                    | 714 016   | Average                              | 737   | Average            | 6 220 102 130 091 360  | Average           | 593 454 459 093 946   | Average                   | 506 011 729 108 959   |
|                  | Max                        | 1 002 370 | Max                                  | 884   | Max                | 10 928 208 758 341 600 | Max               | 1 543 994 683 379 680 | Max                       | 1 551 706 553 529 500 |
|                  | Min                        | 476 190   | Min                                  | 544   | Min                | 2 871 192 491 857 450  | Min               | 37 431 600 000 000    | Min                       | 18 649 100 000 000    |
| Ireland          | Average                    | 65 168    | Average                              | 3 176 | Average            | 183 417 319 462        | Average           | 34 844 109 510        | Average                   | 25 031 501 719        |
|                  | Max                        | 73 880    | Max                                  | 3 714 | Max                | 371 933 096 751        | Max               | 63 218 329 000        | Max                       | 50 432 030 000        |
|                  | Min                        | 56 480    | Min                                  | 2 742 | Min                | 74 965 897 710         | Min               | 9 599 219 873         | Min                       | 6 495 528 000         |
| Italy            | Average                    | 480 622   | Average                              | 2 854 | Average            | 1 637 426 999 860      | Average           | 332 658 121 723       | Average                   | 265 913 203 219       |
|                  | Max                        | 557 230   | Max                                  | 3 215 | Max                | 1 787 732 676 981      | Max               | 441 557 000 000       | Max                       | 351 471 000 000       |
|                  | Min                        | 389 000   | Min                                  | 2 414 | Min                | 1 419 205 741 308      | Min               | 176 724 836 929       | Min                       | 143 286 592 000       |
| Korea            | Average                    | 541 108   | Average                              | 4 042 | Average            | 1 188 477 033 997 190  | Average           | 141 490 639 923 475   | Average                   | 151 523 315 625 000   |
|                  | Max                        | 715 500   | Max                                  | 5 413 | Max                | 1 857 941 377 351 490  | Max               | 294 910 486 322 993   | Max                       | 374 682 700 000 000   |
|                  | Min                        | 280 750   | Min                                  | 2 167 | Min                | 481 065 158 052 239    | Min               | 26 913 000 000 000    | Min                       | 22 008 200 000 000    |
| Mexico           | Average                    | 567 408   | Average                              | 1 557 | Average            | 13 944 352 688 507     | Average           | 1 286 577 227 380     | Average                   | 1 261 473 730 656     |
|                  | Max                        | 674 000   | Max                                  | 1 699 | Max                | 18 433 372 324 373     | Max               | 3 347 460 452 145     | Max                       | 3 097 216 194 000     |
|                  | Min                        | 401 750   | Min                                  | 1 438 | Min                | 8 960 714 868 626      | Min               | 87 062 000 000        | Min                       | 61 949 269 000        |
| Netherlands      | Average                    | 199 896   | Average                              | 4 736 | Average            | 607 586 048 643        | Average           | 115 770 013 247       | Average                   | 130 292 636 531       |
|                  | Max                        | 228 060   | Max                                  | 5 086 | Max                | 765 980 861 402        | Max               | 195 503 000 000       | Max                       | 225 711 000 000       |
|                  | Min                        | 172 230   | Min                                  | 4 233 | Min                | 414 666 766 315        | Min               | 61 251 253 568        | Min                       | 57 060 635 000        |
| Norway           | Average                    | 48 330    | Average                              | 5 758 | Average            | 2 548 596 905 127      | Average           | 511 784 709 677       | Average                   | 464 688 062 500       |
|                  | Max                        | 53 250    | Max                                  | 6 935 | Max                | 3 558 477 728 467      | Max               | 837 475 000 000       | Max                       | 965 837 000 000       |
|                  | Min                        | 43 530    | Min                                  | 4 967 | Min                | 1 481 993 310 953      | Min               | 159 754 000 000       | Min                       | 152 103 000 000       |
| Poland           | Average                    | 375 795   | Average                              | 2 516 | Average            | 1 449 576 961 145      | Average           | 209 317 185 185       | Average                   | 241 501 703 704       |
|                  | Max                        | 420 330   | Max                                  | 2 706 | Max                | 2 248 343 726 925      | Max               | 408 574 000 000       | Max                       | 478 500 000 000       |
|                  | Min                        | 345 450   | Min                                  | 2 314 | Min                | 823 641 725 630        | Min               | 57 372 000 000        | Min                       | 65 188 000 000        |
| Portugal         | Average                    | 69 803    | Average                              | 2 164 | Average            | 169 775 219 001        | Average           | 30 381 996 770        | Average                   | 27 461 483 844        |
|                  | Max                        | 83 070    | Max                                  | 2 519 | Max                | 201 415 432 439        | Max               | 47 593 721 000        | Max                       | 40 112 982 000        |
|                  | Min                        | 56 210    | Min                                  | 1 681 | Min                | 126 935 320 273        | Min               | 9 889 665 905         | Min                       | 8 504 596 000         |
| Russia           | Average                    | 2 349 118 | Average                              | 4 700 | Average            | 72 258 076 322 333     | Average           | 6 315 969 078 075     | Average                   | 7 228 872 446 897     |
|                  | Max                        | 3 015 020 | Max                                  | 5 942 | Max                | 101 641 165 838 539    | Max               | 11 989 394 000 000    | Max                       | 23 124 700 000 000    |
|                  | Min                        | 2 085 050 | Min                                  | 3 981 | Min                | 39 306 158 099 087     | Min               | 542 270 000 000       | Min                       | 133 900 000           |
| Slovakia         | Average                    | 46 294    | Average                              | 3 339 | Average            | 61 866 632 021         | Average           | 10 177 850 577        | Average                   | 10 262 076 969        |
|                  | Max                        | 66 670    | Max                                  | 4 025 | Max                | 87 799 629 576         | Max               | 17 589 988 000        | Max                       | 20 920 765 000        |
|                  | Min                        | 37 210    | Min                                  | 2 943 | Min                | 34 385 959 181         | Min               | 4 594 360 000         | Min                       | 2 636 353 000         |
| South Africa     | Average                    | 452 322   | Average                              | 2 575 | Average            | 3 384 910 835 658      | Average           | 555 449 333 341       | Average                   | 459 028 627 200       |
|                  | Max                        | 560 860   | Max                                  | 2 950 | Max                | 4 769 097 553 786      | Max               | 1 398 839 538 010     | Max                       | 1 199 600 401 599     |
|                  | Min                        | 323 970   | Min                                  | 2 291 | Min                | 2 174 800 491 468      | Min               | 69 098 000 000        | Min                       | 57 362 000 000        |
| Sweden           | Average                    | 62 849    | Average                              | 5 487 | Average            | 3 505 458 511 897      | Average           | 816 947 870 968       | Average                   | 803 184 093 281       |
|                  | Max                        | 78 800    | Max                                  | 5 847 | Max                | 4 717 639 814 281      | Max               | 1 384 237 000 000     | Max                       | 1 411 456 000 000     |
|                  | Min                        | 46 190    | Min                                  | 4 883 | Min                | 2 436 408 217 774      | Min               | 256 030 000 000       | Min                       | 389 967 336 000       |
| Switzerland      | Average                    | 52 263    | Average                              | 3 452 | Average            | 563 382 579 926        | Average           | 49 224 580 674        | Average                   | 62 295 353 313        |
|                  | Max                        | 55 170    | Max                                  | 3 673 | Max                | 710 997 342 304        | Max               | 71 022 374 774        | Max                       | 86 552 196 000        |
|                  | Min                        | 46 500    | Min                                  | 2 960 | Min                | 435 363 996 664        | Min               | 29 365 043 335        | Min                       | 39 913 969 000        |
| Turkey           | Average                    | 326 590   | Average                              | 1 250 | Average            | 1 032 995 599 638      | Average           | 252 955 582 032       | Average                   | 189 972 194 102       |
|                  | Max                        | 500 910   | Max                                  | 1 651 | Max                | 1 922 053 939 443      | Max               | 890 636 678 446       | Max                       | 942 445 923 254       |
|                  | Min                        | 205 440   | Min                                  | 948   | Min                | 506 975 278 400        | Min               | 45 431 200            | Min                       | 43 083 400            |
| United Kingdom   | Average                    | 631 488   | Average                              | 3 503 | Average            | 1 617 419 200 476      | Average           | 346 276 096 774       | Average                   | 275 463 934 563       |
|                  | Max                        | 755 150   | Max                                  | 3 880 | Max                | 2 089 292 317 239      | Max               | 562 218 000 000       | Max                       | 511 269 000 000       |
|                  | Min                        | 440 080   | Min                                  | 2 765 | Min                | 1 143 246 969 963      | Min               | 148 693 000 000       | Min                       | 114 376 696 000       |
| United States    | Average                    | 6 312 413 | Average                              | 7 561 | Average            | 14 901 400 051 509     | Average           | 1 364 412 506 452     | Average                   | 1 939 929 032 258     |
|                  | Max                        | 6 787 480 | Max                                  | 8 057 | Max                | 20 011 233 898 394     | Max               | 2 288 644 900 000     | Max                       | 3 077 990 000 000     |
|                  | Min                        | 5 788 890 | Min                                  | 6 804 | Min                | 9 780 965 227 346      | Min               | 624 060 000 000       | Min                       | 948 186 000 000       |

The use of the estimated fiscal policy index pretends to determine whether the current fiscal policy, as a whole of the sample countries, is impacting the environmental improvement.

Through the results presented in the Table 3, eigenvalues presented show that the first component is explaining, for all countries, a higher standard variation in the dependent variable than the other component, thus, it is possible to conclude that the first component determined is the most pertinent to define the fiscal policy index. For all the countries, the eigenvalues present a value higher than 90% for the first component.

**Table III:** Results of Principal Component analysis (PCA)

| Country        |           |            |            |            |            |
|----------------|-----------|------------|------------|------------|------------|
| Australia      | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.9863     | 1.9726     | 0.9932     | 0.9932     |
|                | PC2       | 0.0136984  | -----      | 0.0068     | 1          |
| Austria        | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.98473    | 1.96947    | 0.9924     | 0.9924     |
|                | PC2       | 0.0152675  | -----      | 0.0076     | 1          |
| Belgium        | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.97159    | 1.94318    | 0.9858     | 0.9858     |
|                | PC2       | 0.0284108  | -----      | 0.0142     | 1          |
| Canada         | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.88739    | 1.77479    | 0.9437     | 0.9437     |
|                | PC2       | 0.112606   | -----      | 0.0563     | 1          |
| Czech Republic | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.973374   | 1.94748    | 0.9869     | 0.9869     |
|                | PC2       | 0.0262617  | -----      | 0.0131     | 1          |
| Denmark        | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.97328    | 1.94656    | 0.9866     | 0.9866     |
|                | PC2       | 0.026719   | -----      | 0.0134     | 1          |
| Finland        | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.93418    | 1.86837    | 0.9671     | 0.9671     |
|                | PC2       | 0.0658159  | -----      | 0.0329     | 1          |
| France         | Component | EigenValue | Difference | Proportion | Cumulative |
|                |           |            |            |            |            |
|                | PC1       | 1.9809     | 1.96179    | 0.9904     | 0.9904     |
|                | PC2       | 0.0191027  | -----      | 0.0096     | 1          |

**Table III:** Results of Principal Component analysis (PCA) (Continuation)

| Country        | Component | EigenValue | Difference | Proportion | Cumulative |
|----------------|-----------|------------|------------|------------|------------|
| Germany        |           |            |            |            |            |
|                | PC1       | 1.93203    | 1.86406    | 0.966      | 0.966      |
|                | PC2       | 0.0679722  | -----      | 0.034      | 1          |
| Greece         |           |            |            |            |            |
|                | PC1       | 1.91934    | 1.83869    | 0.9597     | 0.9597     |
|                | PC2       | 0.0806572  | -----      | 0.0403     | 1          |
| Hungary        |           |            |            |            |            |
|                | PC1       | 1.99488    | 1.98975    | 0.9974     | 0.9974     |
|                | PC2       | 0.00512    | -----      | 0.0026     | 1          |
| India          |           |            |            |            |            |
|                | PC1       | 1.9962     | 1.99241    | 0.9981     | 0.9981     |
|                | PC2       | 0.0038     | -----      | 0.0019     | 1          |
| Indonesia      |           |            |            |            |            |
|                | PC1       | 1.98586    | 1.97173    | 0.9929     | 0.9929     |
|                | PC2       | 0.01414    | -----      | 0.0071     | 1          |
| Ireland        |           |            |            |            |            |
|                | PC1       | 1.87105    | 1.74211    | 0.9355     | 0.9355     |
|                | PC2       | 0.12895    | -----      | 0.0645     | 1          |
| Italy          |           |            |            |            |            |
|                | PC1       | 1.97664    | 1.95328    | 0.9883     | 0.9883     |
|                | PC2       | 0.02336    | -----      | 0.0117     | 1          |
| Korea          |           |            |            |            |            |
|                | PC1       | 1.98084    | 1.96168    | 0.9904     | 0.9904     |
|                | PC2       | 0.01916    | -----      | 0.0096     | 1          |
| Mexico         |           |            |            |            |            |
|                | PC1       | 1.97522    | 1.95043    | 0.9876     | 0.9876     |
|                | PC2       | 0.02478    | -----      | 0.0124     | 1          |
| Netherlands    |           |            |            |            |            |
|                | PC1       | 1.9578     | 1.91576    | 0.9789     | 0.9789     |
|                | PC2       | 0.0422     | -----      | 0.0211     | 1          |
| Norway         |           |            |            |            |            |
|                | PC1       | 1.9078     | 1.8156     | 0.9539     | 0.9539     |
|                | PC2       | 0.0922     | -----      | 0.0461     | 1          |
| Poland         |           |            |            |            |            |
|                | PC1       | 1.98431    | 1.96862    | 0.9922     | 0.9922     |
|                | PC2       | 0.01569    | -----      | 0.0078     | 1          |
| Portugal       |           |            |            |            |            |
|                | PC1       | 1.97401    | 1.94802    | 0.987      | 0.987      |
|                | PC2       | 0.02599    | -----      | 0.013      | 1          |
| Russia         |           |            |            |            |            |
|                | PC1       | 1.9225     | 1.84501    | 0.9613     | 0.9613     |
|                | PC2       | 0.0775     | -----      | 0.0387     | 1          |
| Slovakia       |           |            |            |            |            |
|                | PC1       | 1.97115    | 1.94229    | 0.9856     | 0.9856     |
|                | PC2       | 0.02885    | -----      | 0.0144     | 1          |
| South Africa   |           |            |            |            |            |
|                | PC1       | 1.9998     | 1.98159    | 0.9954     | 0.9954     |
|                | PC2       | 0.0002     | -----      | 0.0046     | 1          |
| Sweden         |           |            |            |            |            |
|                | PC1       | 1.95481    | 1.99962    | 0.9774     | 0.9774     |
|                | PC2       | 0.04519    | -----      | 0.0226     | 1          |
| Switzerland    |           |            |            |            |            |
|                | PC1       | 1.9489     | 1.8978     | 0.9744     | 0.9744     |
|                | PC2       | 0.0511     | -----      | 0.0256     | 1          |
| Turkey         |           |            |            |            |            |
|                | PC1       | 1.99227    | 1.98454    | 0.9961     | 0.9961     |
|                | PC2       | 0.00773    | -----      | 0.0039     | 1          |
| United Kingdom |           |            |            |            |            |
|                | PC1       | 1.96723    | 1.93446    | 0.9836     | 0.9836     |
|                | PC2       | 0.03277    | -----      | 0.0164     | 1          |
| United States  |           |            |            |            |            |
|                | PC1       | 1.87167    | 1.74334    | 0.9358     | 0.9358     |
|                | PC2       | 0.12833    | -----      | 0.0642     | 1          |

## 4. Empirical Methodology and Results

### 4.1. Time Series Properties: stationary and Cointegration

In this study the main goal is to test if the degradation of the environment, proxied by GHG, will be influenced by fiscal policy. The systems used were E-views 12 and Stata SE17.

Based on the EKC theoretical model (Kuznets, 1955), the following augmented reduced-form equation was explored:

$$GHG = f(GDP; FPI; EC; ) \quad (1)$$

$$GHG_{it} = \alpha_i dt + \delta_{1i} Y_{it+} + \delta_{2i} FPI_{it} + \delta_{3i} EC + \delta_{4i} FPI * FPI + \varepsilon_t \quad (2)$$

Where  $GHG_{it}$  stands for the total greenhouse gas emissions (kt of CO<sub>2</sub> equivalent), Y is the GDP per capita, FPI is the Fiscal policy index, EC stands for Energy consumption in Kt, and  $\varepsilon_t$  is the error term. The variables were transformed in Ln to consider the relative proportional impact that each variable has on the dependent variable, with exception of FPI that is an index.

$$\ln GHG_{it} = \alpha_i dt + \delta_{1i} \ln Y_{it+} + \delta_{2i} FPI_{it} + \delta_{3i} \ln EC + \delta_{4i} FPI * FPI + \varepsilon_t \quad (3)$$

Under the variables selected, it is necessary to study the stationary status of the time series (Waheed et al., 2006). To test for the presence of unit roots, the Augmented Dickey-Fuller (ADF) (Cheung et al., 1995) was employed. The test is expressed by the following equation:

$$Y_t = c + \beta_t + \alpha y_{t-1} + \theta_1 \Delta Y_{t-1} + \theta_2 \Delta Y_{t-2} \dots + \theta_p \Delta Y_{t-p} + \varepsilon_t \quad (4)$$

$$Y_t = c + \beta_t + \alpha y_{t-1} + \sum_{i=1}^k \theta_i \Delta y_{t-i} + \varepsilon_t \quad (5)$$

Equation (5) should be applied to perform the test:

$$H_0: \alpha = 1, \text{ we are in presence of a unit root}$$

$$H_1: \alpha < 1, \text{ we are not in presence of a unit root}$$

As the null hypothesis assumes the presence of a  $\alpha = 1$ , the p-value (0.05) should be less than the significance value to prove that the Series is stationary.

The results for the ADF test are presented in table 4, and through the output we can conclude we are in a presence of variables with I (1), integrated of 1<sup>st</sup> order, although we

have some integrated of 2<sup>nd</sup> order, I(2), variables that were differentiated in order to apply the respective cointegration test and proceed with the study.

**Table IV:** ADF Test results<sup>3</sup>

| ADF test       | I(0)   |               |               |               | I(1)          |               |               |               | I(2) |     |               |               |
|----------------|--------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|------|-----|---------------|---------------|
|                | LGHG   | LEC           | LGDP          | FPI           | LGHG          | LEC           | LGDP          | FPI           | LGHG | LEC | LGDP          | FPI           |
| Australia      | 0,9476 | 0,6821        | <b>0,0334</b> | 1,0000        | <b>0,0001</b> | <b>0,0001</b> | --            | <b>0,0001</b> | --   | --  | --            | --            |
| Austria        | 0,1693 | 0,3194        | 0,1693        | 0,4452        | <b>0,0001</b> | <b>0,0002</b> | <b>0,0001</b> | <b>0,0001</b> | --   | --  | --            | --            |
| Belgium        | 0,4727 | 0,3671        | <b>0,0004</b> | 0,5039        | <b>0,0000</b> | <b>0,0001</b> | --            | <b>0,0215</b> | --   | --  | --            | --            |
| Canada         | 0,0525 | 0,0822        | <b>0,0025</b> | 0,7082        | <b>0,0000</b> | <b>0,0001</b> | --            | <b>0,0017</b> | --   | --  | --            | --            |
| Czech Republic | 0,1794 | 0,2349        | <b>0,0062</b> | 0,2435        | <b>0,0003</b> | <b>0,0008</b> | --            | <b>0,0223</b> | --   | --  | --            | --            |
| Denmark        | 0,6795 | <b>0,0378</b> | 0,7862        | 0,2973        | <b>0,0003</b> | --            | <b>0,0002</b> | <b>0,0001</b> | --   | --  | --            | --            |
| Finland        | 0,9084 | 0,8574        | 0,9191        | 0,0669        | <b>0,0001</b> | <b>0,0002</b> | <b>0,0050</b> | <b>0,0374</b> | --   | --  | --            | --            |
| France         | 0,6667 | 0,9674        | 0,9856        | 0,1363        | <b>0,0021</b> | <b>0,0001</b> | <b>0,0002</b> | <b>0,0186</b> | --   | --  | --            | --            |
| Germany        | 0,0756 | 0,1219        | <b>0,0174</b> | 0,9396        | <b>0,0001</b> | <b>0,0001</b> | --            | <b>0,0196</b> | --   | --  | --            | --            |
| Greece         | 0,9946 | 0,8970        | 0,7284        | 0,9902        | <b>0,0229</b> | <b>0,0001</b> | 0,7120        | <b>0,0442</b> | --   | --  | <b>0,0001</b> | --            |
| Hungary        | 0,4718 | 0,4114        | <b>0,0384</b> | 0,4952        | <b>0,0037</b> | <b>0,0107</b> | --            | 0,1081        | --   | --  | --            | <b>0,0001</b> |
| India          | 0,0518 | 0,7007        | 0,1187        | 0,9994        | <b>0,0038</b> | <b>0,0003</b> | <b>0,0291</b> | <b>0,0003</b> | --   | --  | --            | --            |
| Indonesia      | 0,5922 | 0,4904        | 0,9995        | 0,6195        | <b>0,0043</b> | <b>0,0071</b> | <b>0,0006</b> | 0,9985        | --   | --  | --            | <b>0,0301</b> |
| Ireland        | 0,6358 | 0,8909        | 0,6330        | 0,1207        | <b>0,0350</b> | <b>0,0024</b> | 0,0699        | 0,0953        | --   | --  | <b>0,0001</b> | <b>0,0016</b> |
| Italy          | 0,7312 | 0,7763        | 0,7503        | 0,9968        | <b>0,0002</b> | <b>0,0004</b> | <b>0,0001</b> | <b>0,0319</b> | --   | --  | --            | --            |
| Korea          | 0,1361 | 0,4069        | 0,9184        | 0,8186        | <b>0,0255</b> | <b>0,0054</b> | 0,0926        | <b>0,0079</b> | --   | --  | <b>0,0005</b> | --            |
| Mexico         | 0,9812 | 0,9944        | <b>0,0035</b> | 0,9166        | <b>0,0065</b> | <b>0,0004</b> | --            | 0,0936        | --   | --  | --            | <b>0,0037</b> |
| Netherlands    | 0,8691 | 0,8611        | 0,8914        | 0,1184        | <b>0,0002</b> | <b>0,0156</b> | <b>0,0213</b> | 0,0951        | --   | --  | --            | <b>0,0006</b> |
| Norway         | 0,3989 | <b>0,0277</b> | 0,7753        | 0,5623        | <b>0,0079</b> | --            | <b>0,0026</b> | <b>0,0185</b> | --   | --  | --            | --            |
| Poland         | 0,6276 | 0,4186        | <b>0,0249</b> | 0,7997        | <b>0,0001</b> | <b>0,0025</b> | --            | 0,1655        | --   | --  | --            | <b>0,0099</b> |
| Portugal       | 0,8364 | 0,8921        | 0,2101        | 0,7082        | <b>0,0007</b> | <b>0,0014</b> | <b>0,0101</b> | <b>0,0017</b> | --   | --  | --            | --            |
| Russia         | 0,2651 | 0,3258        | 0,8430        | <b>0,0239</b> | <b>0,0421</b> | <b>0,0238</b> | <b>0,0001</b> | --            | --   | --  | --            | --            |
| Slovakia       | 0,1155 | 0,0525        | 0,9368        | 0,8440        | <b>0,0001</b> | <b>0,0001</b> | <b>0,0017</b> | <b>0,0019</b> | --   | --  | --            | --            |
| South Africa   | 0,9737 | 0,8868        | 0,9974        | 0,4152        | <b>0,0002</b> | <b>0,0001</b> | <b>0,0006</b> | 0,3766        | --   | --  | --            | <b>0,0008</b> |
| Sweden         | 0,0798 | <b>0,0044</b> | 0,3496        | 0,5609        | <b>0,0318</b> | --            | <b>0,0001</b> | <b>0,0139</b> | --   | --  | --            | --            |
| Switzerland    | 0,9974 | 0,3462        | 0,8353        | 0,2215        | <b>0,0161</b> | <b>0,0001</b> | <b>0,0046</b> | <b>0,0001</b> | --   | --  | --            | --            |
| Turkey         | 0,0965 | 0,1211        | <b>0,0315</b> | 1,0000        | <b>0,0043</b> | <b>0,0001</b> | --            | 1,0000        | --   | --  | --            | 0,0005        |
| United Kingdom | 0,3900 | 0,1537        | 0,8678        | 0,5102        | <b>0,0193</b> | <b>0,0001</b> | <b>0,0006</b> | <b>0,0021</b> | --   | --  | --            | --            |
| United States  | 0,9611 | 0,5165        | 0,8145        | <b>0,0057</b> | <b>0,0001</b> | <b>0,0001</b> | <b>0,0015</b> | --            | --   | --  | --            | --            |

**4.1.1. Tests for Cointegration**

Under the results presented in the Table 4, it was possible to confirm that, for some countries, all variables become stationary after the first difference. Under this scenario, the majority are in the same order of integration, I(1).

In the literature we have two main tests that we can apply in this scenario, Engle-Granger integration test (Engle et al., 1987) and Johansen Cointegration Test (Johansen, 1988). In this study was followed the Johansen Cointegration test for countries that all variables are I(1).

This process has the advantage of avoiding losing information regarding equilibrium relationship and properties of long-run relationship, which could lead to a result without meaning or incorrect.

The Johansen cointegration approach tests the following hypothesis:

$$H_0: \text{no cointegration}$$

<sup>3</sup> The test was performed with Trend and intercept for all the variables, with annual data from 1990-2021 with lag 2 according to Akaike Information Criteria (AIC).

$H_1$ : cointegration

This approach has two statistical approaches to study the significance of the respective vectors, the trace and the Maximum Eigenvalue. For both, the critical values are based in Mackinnon-Haug-Michelis (1999).

In the first part of the output test, we can find the trace tests, and the null hypothesis is that exists  $r$  integration vectors. The Maximum Eigen Values has as null hypothesis testing the maximum  $r$  vectors of cointegration and has as  $H_1$  the hypothesis of  $r+1$  integration vectors.

Table V. Johansen Cointegration Test

|                | Hypothesized No. of CE(s) | Eigenvalue | Trace Statistics | 0.05 Critical Value | P-value | Maximum Eigenvalue | Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistics | 0.05 Critical Value | P-value |
|----------------|---------------------------|------------|------------------|---------------------|---------|--------------------|---------------------------|------------|----------------------|---------------------|---------|
| Austria        | None                      | 0.716822   | 59.384690        | 47.856130           | 0.0029  | Austria            | None                      | 0.716822   | 35.326990            | 27.584340           | 0.0042  |
|                | At most 1                 | 0.429894   | 24.057700        | 29.797070           | 0.1980  |                    | At most 1                 | 0.429894   | 15.734130            | 21.131620           | 0.2408  |
|                | At most 2                 | 0.246248   | 8.323570         | 15.494710           | 0.4315  |                    | At most 2                 | 0.246248   | 7.915387             | 14.264600           | 0.3873  |
|                | At most 3                 | 0.014472   | 0.408183         | 3.841465            | 0.5229  |                    | At most 3                 | 0.014472   | 0.408183             | 3.841465            | 0.5229  |
| Finland        | None                      | 0.573210   | 45.607260        | 40.174930           | 0.0129  | Finland            | None                      | 0.573210   | 23.840940            | 24.159210           | 0.0552  |
|                | At most 1                 | 0.375674   | 21.766320        | 24.275960           | 0.1003  |                    | At most 1                 | 0.375674   | 13.190310            | 17.797300           | 0.2158  |
|                | At most 2                 | 0.257784   | 8.576015         | 12.320900           | 0.1954  |                    | At most 2                 | 0.257784   | 8.347222             | 11.224800           | 0.1534  |
|                | At most 3                 | 0.008138   | 0.228793         | 4.129906            | 0.6903  |                    | At most 3                 | 0.008138   | 0.228793             | 4.129906            | 0.6903  |
| France         | None                      | 0.654877   | 52.283090        | 47.856130           | 0.0181  | France             | None                      | 0.654877   | 30.851810            | 27.584340           | 0.0183  |
|                | At most 1                 | 0.368733   | 21.431270        | 29.797070           | 0.3313  |                    | At most 1                 | 0.368733   | 13.340780            | 21.131620           | 0.4214  |
|                | At most 2                 | 0.239897   | 8.090489         | 15.494710           | 0.4458  |                    | At most 2                 | 0.239897   | 7.954739             | 14.264600           | 0.3833  |
|                | At most 3                 | 0.004670   | 0.135750         | 3.841465            | 0.7125  |                    | At most 3                 | 0.004670   | 0.135750             | 3.841465            | 0.7125  |
| India          | None                      | 0.773171   | 65.131000        | 47.856130           | 0.0006  | India              | None                      | 0.773171   | 40.056040            | 27.584340           | 0.0008  |
|                | At most 1                 | 0.517512   | 25.074960        | 29.797070           | 0.1588  |                    | At most 1                 | 0.517512   | 19.677570            | 21.131620           | 0.0788  |
|                | At most 2                 | 0.179612   | 5.397390         | 15.494710           | 0.7653  |                    | At most 2                 | 0.179612   | 5.345413             | 14.264600           | 0.6977  |
|                | At most 3                 | 0.001923   | 0.051978         | 3.841465            | 0.8196  |                    | At most 3                 | 0.001923   | 0.051978             | 3.841465            | 0.8196  |
| Italy          | None                      | 0.537351   | 42.985920        | 40.174930           | 0.0254  | Italy              | None                      | 0.537351   | 22.352780            | 24.159210           | 0.0862  |
|                | At most 1                 | 0.292875   | 20.633130        | 24.275960           | 0.1346  |                    | At most 1                 | 0.292875   | 10.049890            | 17.797300           | 0.4800  |
|                | At most 2                 | 0.214439   | 10.583240        | 12.320900           | 0.0961  |                    | At most 2                 | 0.214439   | 6.999361             | 11.224800           | 0.2496  |
|                | At most 3                 | 0.116251   | 3.583882         | 4.129906            | 0.0692  |                    | At most 3                 | 0.116251   | 3.583882             | 4.129906            | 0.0692  |
| Korea          | None                      | 0.630278   | 50.378070        | 47.856130           | 0.0059  | Korea              | None                      | 0.630278   | 28.855120            | 27.584340           | 0.0342  |
|                | At most 1                 | 0.370634   | 21.925590        | 29.797070           | 0.3026  |                    | At most 1                 | 0.370634   | 13.428230            | 21.131620           | 0.4136  |
|                | At most 2                 | 0.253446   | 8.497356         | 15.494710           | 0.4138  |                    | At most 2                 | 0.253446   | 8.476341             | 14.264600           | 0.3323  |
|                | At most 3                 | 0.000724   | 0.021015         | 3.841465            | 0.8846  |                    | At most 3                 | 0.000724   | 0.021015             | 3.841465            | 0.8846  |
| Netherlands    | None                      | 0.760766   | 80.385610        | 63.876100           | 0.0011  | Netherlands        | None                      | 0.760766   | 41.479080            | 32.118320           | 0.0027  |
|                | At most 1                 | 0.483393   | 38.906540        | 42.915250           | 0.1190  |                    | At most 1                 | 0.483393   | 19.153700            | 25.823210           | 0.2950  |
|                | At most 2                 | 0.301298   | 19.752830        | 25.872110           | 0.2387  |                    | At most 2                 | 0.301298   | 10.397380            | 19.387040           | 0.5764  |
|                | At most 3                 | 0.275738   | 9.355449         | 12.517980           | 0.1596  |                    | At most 3                 | 0.275738   | 9.355449             | 12.517980           | 0.1596  |
| Portugal       | None                      | 0.839637   | 80.806390        | 47.856130           | 0.0000  | Portugal           | None                      | 0.839637   | 42.097260            | 27.584340           | 0.0004  |
|                | At most 1                 | 0.542341   | 38.709130        | 29.797070           | 0.0036  |                    | At most 1                 | 0.542341   | 17.977500            | 21.131620           | 0.1307  |
|                | At most 2                 | 0.475971   | 20.731630        | 15.494710           | 0.0074  |                    | At most 2                 | 0.475971   | 14.862810            | 14.264600           | 0.0402  |
|                | At most 3                 | 0.225212   | 5.868824         | 3.841465            | 0.0154  |                    | At most 3                 | 0.225212   | 5.868824             | 3.841465            | 0.0154  |
| Slovakia       | None                      | 0.745330   | 52.928810        | 47.856130           | 0.0155  | Slovakia           | None                      | 0.745330   | 31.459090            | 27.584340           | 0.0151  |
|                | At most 1                 | 0.431728   | 21.469720        | 29.797070           | 0.3290  |                    | At most 1                 | 0.431728   | 12.998570            | 21.131620           | 0.4524  |
|                | At most 2                 | 0.213886   | 8.471155         | 15.494710           | 0.4165  |                    | At most 2                 | 0.213886   | 5.535020             | 14.264600           | 0.6733  |
|                | At most 3                 | 0.119846   | 2.936134         | 3.841465            | 0.0866  |                    | At most 3                 | 0.119846   | 2.936134             | 3.841465            | 0.0866  |
| South Africa   | None                      | 0.578771   | 47.308810        | 47.856130           | 0.0562  | South Africa       | None                      | 0.578771   | 25.072810            | 27.584340           | 0.1014  |
|                | At most 1                 | 0.396191   | 22.236010        | 29.797070           | 0.2856  |                    | At most 1                 | 0.396191   | 14.630410            | 21.131620           | 0.3156  |
|                | At most 2                 | 0.199236   | 7.605598         | 15.494710           | 0.5085  |                    | At most 2                 | 0.199236   | 6.443481             | 14.264600           | 0.5570  |
|                | At most 3                 | 0.039281   | 1.162117         | 3.841465            | 0.2810  |                    | At most 3                 | 0.039281   | 1.162117             | 3.841465            | 0.2810  |
| Switzerland    | None                      | 0.696749   | 68.200780        | 63.876100           | 0.0207  | Switzerland        | None                      | 0.696749   | 33.409460            | 32.118320           | 0.0346  |
|                | At most 1                 | 0.418081   | 34.791310        | 42.915250           | 0.2538  |                    | At most 1                 | 0.418081   | 15.159860            | 25.823210           | 0.6201  |
|                | At most 2                 | 0.390836   | 19.631450        | 25.872110           | 0.2452  |                    | At most 2                 | 0.390836   | 13.878680            | 19.387040           | 0.2624  |
|                | At most 3                 | 0.185724   | 5.751766         | 12.517980           | 0.4923  |                    | At most 3                 | 0.185724   | 5.752766             | 12.517980           | 0.4923  |
| United Kingdom | None                      | 0.614170   | 58.143700        | 47.856130           | 0.0040  | United Kingdom     | None                      | 0.614170   | 27.618370            | 27.584340           | 0.0495  |
|                | At most 1                 | 0.418923   | 30.525320        | 29.797070           | 0.0412  |                    | At most 1                 | 0.418923   | 15.743270            | 21.131620           | 0.2402  |
|                | At most 2                 | 0.304937   | 14.782060        | 15.494710           | 0.0638  |                    | At most 2                 | 0.304937   | 10.548850            | 14.264600           | 0.1783  |
|                | At most 3                 | 0.135819   | 4.233209         | 3.841465            | 0.0396  |                    | At most 3                 | 0.135819   | 4.233209             | 3.841465            | 0.0396  |

In order to analyze the long-run relationships, after calculating the results for equation (6) and confirm that for some countries the variables are I(1) and I(0), it is necessary to perform the F-bound tests in order to check if we are in the presence of a long run relationship of the variables or not, an approach developed by Pesaran & Shin (1999) and Pesaran et al. (2001).

For series that are integrated with different orders it's also required to perform test of cointegration, although in this case it is not possible to use the Johansen Cointegration Test.

The hypothesis for the test is the following:

$$H_0: \mu_1 = \mu_2 = 0, \text{No long run relationship}$$

$$H_1: \mu_1 \neq 0 \cup \mu_2 \neq 0, \text{Existence of long run relationship}$$

If our results show a F-statistic higher than the upper bound critical value, then we can conclude that we are in the presence of a long run relationship in the model. As a result, it's needed to perform the estimation of a long run model, that is Error correction Model (ECM). If the F statistic is lower than the lower bound critical, then we can conclude that we are in a presence of a no cointegration between the variables and no long run relationship among the variables of the model. That is, it should be analyzed the short-run model through the Autoregressive Distributed Lag (ARDL) model. If the F-statistics is between the lower bound of I (0) and upper bound I(1) the relation is inconclusive.

The results for the test are presented in the table below. Although the Johansen test was calculated for the countries with only I(1), the F-statistic test was also applied for those countries to reinforce the result obtained.

Through the results presented in table 6, 22 countries showed a cointegration relationship, given the value for the F-statistic is higher that the upper bound I(1).

**Table VI:** F-statistic Results (Significance at 5%| \*\* significance at 10%)

| Country        | F-statistic | I(0) | I(1) |
|----------------|-------------|------|------|
| Australia      | 4,39        | 2,86 | 4,01 |
| Austria        | 9,23        | 2,86 | 4,01 |
| Belgium        | 4,35        | 2,86 | 4,01 |
| Canada         | 8,36        | 2,86 | 4,01 |
| Czech Republic | 3,23        | 2,86 | 4,01 |
| Denmark        | 9,59        | 3,23 | 4,35 |
| Finland**      | 3,93        | 2,45 | 3,52 |
| France         | 9,37        | 2,86 | 4,01 |
| Germany        | 2,71        | 2,86 | 4,01 |
| Greece         | 2,20        | 2,86 | 4,01 |
| Hungary        | 4,05        | 2,86 | 4,01 |
| India          | 12,28       | 2,86 | 4,01 |
| Indonesia      | 1,69        | 2,86 | 4,01 |
| Ireland        | 7,06        | 2,86 | 4,01 |
| Italy          | 4,09        | 2,86 | 4,01 |
| Korea          | 2,88        | 2,86 | 4,01 |
| Mexico         | 4,06        | 2,86 | 4,01 |
| Netherlands**  | 3,90        | 2,45 | 3,52 |
| Norway**       | 3,86        | 2,45 | 3,52 |
| Poland         | 3,04        | 2,86 | 4,01 |
| Portugal       | 4,46        | 2,86 | 4,01 |
| Russia         | 18,06       | 2,86 | 4,01 |
| Slovakia       | 16,58       | 2,86 | 4,01 |
| South Africa   | 2,25        | 2,86 | 4,01 |
| Sweden         | 4,06        | 2,86 | 4,01 |
| Switzerland    | 4,88        | 2,86 | 4,01 |
| Turkey         | 10,18       | 2,86 | 4,01 |
| United Kingdom | 4,92        | 2,86 | 4,01 |
| United States  | 5,71        | 2,86 | 4,01 |

## 4.2. Autoregressive Distributed Lag Model

To analyze the effectiveness of the fiscal policy on the environment, the model applied will follow the ARDL Model (Pesaran et al., 2001) modeling approach.

Unlike the Autoregression Model (VAR), which has more applicability for endogenous variables, the ARDL, which is an ordinary least square model, is applicable for both endogenous and exogenous variables.

It was decided to use this model since it enables us to have more robust results in our analysis, enables to distinguish the presence of a single long-run relationship between

the dependent and explanatory variables, and in a presence of multiple cointegrated vectors it enables us to identify them through a linear modification.

Additionally, the choice of the model was also based on the integration order of the respective variables presented in the model. Through the Error Correction Model (ECM), it is possible to test integrated variables at different degrees,  $I(0)$  and  $(1)$  or just  $I(1)$ , and for both short-term and long-term can be tested (Pesaran et al.,2001).

The general equation is based on the dependent variable,  $Y$ , and independent variable,  $X$ .

$$Y = f(X) \quad (6)$$

By the work of Pesaran et al. (1999) and Pesaran et al. (2001) the ARDL (p,q) model can be defined by the below equation:

$$y_t = \beta_0 + \sum_{i=1}^q \delta_1 y_{t-i} + \sum_{j=0}^p \sigma_j x_{t-j} + \varepsilon_t \quad (7)$$

The component  $\varepsilon_t$  is the error term and  $\beta_0$  is the constant term. The coefficients for short term are represented by  $\delta_1$  and  $\sigma_j$ ,  $\forall j \geq 1$ .

To conduct the ARDL model we need to follow the lag estimation, thus, the method applied was the Akaike Information Criteria (AIC).

The regression estimated was the following:

$$\Delta LGHG_t = \mu + \alpha_1 LGHG_{t-i} + \beta_0 LGDP_t + \beta_1 LGDP_{t-i} + \beta_2 LEC_t + \beta_3 LEC_{t-i} + \beta_4 dFP_t + \beta_5 dFP_{t-i} + \beta_6 dFP_{t-i} * dFP_{t-i} \quad (8)$$

With the existence of a long run cointegration relationship, it is necessary to perform the calculation of the ECM through the following equation in order to define the dynamics of long and short term:

$$\Delta y_t = \beta_0 + \sum_{i=1}^q \delta_1 y_{t-i} + \sum_{j=0}^p \sigma_j x_{t-j} + \mu_1 y_{t-1} + \mu_2 x_{t-1} + \varepsilon_t \quad (9)$$

### 4.3. Model Diagnosis

The last part of the methodology is to test our model regarding Heteroskedasticity and stability of the model, by testing the residuals autocorrelation.

To test the autocorrelation, was performed the Breusch-Godfrey test. The results are presented in Appendix.

Autocorrelation function (ACF) is the term used to define the correlation coefficient between two values in a temporal Serie. The autocorrelation is null when:

$$Cov(\varepsilon_i; \varepsilon_j) = 0 \text{ for all } j \neq i \quad (10)$$

Autocorrelation in a model occurs due to bad specification of the model or simply missing dynamic, and is present when the residuals are not independent, which would suggest the independent error in the model is incorrect. This condition is often violated in time-series variables which normally present dependence.

In a presence of autocorrelation, the model will be inefficient, and the covariance matrix will take another form. The estimators would not be affected, nevertheless, the conclusion may not be reliable.

Heteroscedasticity occurs in a model when a constant variance is not verified for the error term. Heteroscedasticity violates the homoskedasticity, which is represented as below (where  $X_i$  denotes the explained variable):

$$var(\varepsilon_i|X_i) = \sigma^2 \quad \text{for all } i \quad (11)$$

In a presence of Heteroscedasticity, the conditional variance of errors is not constant, expressed by the equation below (where  $X_i$  denotes the explained variable):

$$var(\varepsilon_i|X_i) = \sigma_i^2 \quad \text{for all } i \quad (12)$$

Under a model with heteroscedasticity, independent variables will have assigned some fluctuations of the error term, the model will have unreliable hypothesis of testing.

In order to test the stability of the model it was followed the cumulative sum control chart test (CUSUM), which is used to monitor whether we are a in presence of a process that is moving away from its mean. By analysing for each country, it was possible to observe that all models are stable as shown in the graphics in Appendix.

## 5. Discussion

The main goal of this work was to perform a study in the effectiveness of fiscal policy on the environment through the long-run relationship between GHG, FPI, EC and GDP. The steps followed to perform these analyses were previously mentioned, (1) perform the PCA model in order to determine the fiscal policy index (2) perform stationary ADF tests (3) model specification (4) cointegration test (5) tests for heteroskedasticity and autocorrelation. Through the cointegration tests performed we were able to conclude that the following countries have a long-run relationship between fiscal policy and GHG:

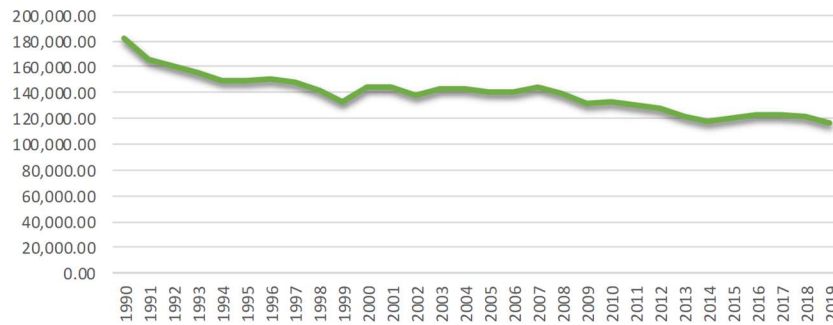
**Table VII:** Cointegration Test Results (\*\* significance at 10%)

| Country        | Cointegration |
|----------------|---------------|
| Australia      | YES           |
| Austria        | YES           |
| Belgium        | YES           |
| Canada         | YES           |
| Czech Republic | <b>NO</b>     |
| Denmark        | YES           |
| Finland**      | YES           |
| France         | YES           |
| Germany        | <b>NO</b>     |
| Greece         | <b>NO</b>     |
| Hungary        | YES           |
| India          | YES           |
| Indonesia      | <b>NO</b>     |
| Ireland        | YES           |
| Italy          | YES           |
| Korea          | <b>NO</b>     |
| Mexico         | YES           |
| Netherlands**  | YES           |
| Norway**       | YES           |
| Poland         | <b>NO</b>     |
| Portugal       | YES           |
| Russia         | YES           |
| Slovakia       | YES           |
| South Africa   | <b>NO</b>     |
| Sweden         | YES           |
| Switzerland    | YES           |
| Turkey         | YES           |
| United Kingdom | YES           |
| United States  | YES           |

According to the results obtained, seven countries have no long-term relationship between fiscal policy and environmental degradation (measured through GHG emissions), which will be analysed more closely to understand which factors may be impacting the results obtained. Being that said, we will analyse more closely, Czech Republic, Germany, Greece, Indonesia, Korea, Poland, and South Africa.

One of the countries with no evidence is Czech Republic, that is one of the most energy-carbon economies in the Organisation for Economic Co-operation and Development (OECD) and considered by the CCPI on the 51<sup>o</sup> rank.. It is a country with few natural resources, has the largest deposits of coal reserves in the Upper Silesian coal basin, and

the industry sector represents 37.8% of total GDP and services sector 58%, which means a higher energy intensity and therefore, a big share of greenhouse emissions.



Note: 2020 and 2021 not available for Greenhouse gas emissions in Czech Republic

**Figure 1:** Czech Republic total Greenhouse Gas Emissions (kT of CO<sub>2</sub> equivalent) (Source: World bank/OECD)

The energy mix is composed by 81% of non-renewable energy and 19% of renewable energy (IEA), and the country is fully-self sufficient in producing electricity. Domestic electricity production is provided by Local nuclear power stations, representing a total of 33%. The new era for renewable energy started in 2005, when the new Act of renewable sources was taken and the main sector of renewable energy in the country is the Bioenergy ( biomass, biogas and biofuels).

The Environment tax reform was done in 2018 in Czech Republic, meaning the taxation of electricity, solid fuels and natural gas, allocated the country in the 24<sup>th</sup> position of higher tax rate on energy compared to worldwide basis.

Showing a 19% of renewable energy sector, would be expected no result would change with the decoupling of the energy variable in the model of this study, once Czech republic represents a lower percentage of energy renewable policies in the country, and is needed to be reviewed by the policymakers the green energy fiscal policy after the misguided policy on photovoltaics in 2008, that led to business opportunities instead of environmental benefits ( Dvorak et al.,2017)

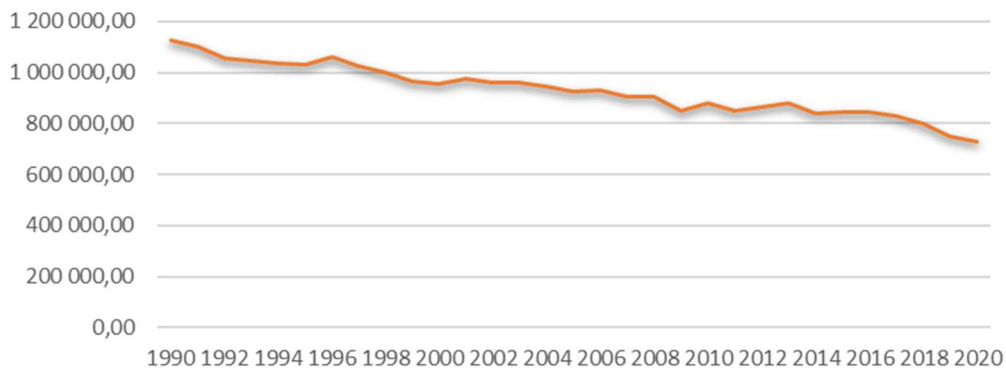
Although the environmental quality has been improving as can be seen in the data from figure 1, Czech Republic has a big path to perform. It was released for environmental protection a strategy report called *Circular Czechia 2040* with a full strategy to improve the green path in this country, aligned with the European Union Action Plan for the circular economy (European Commission, 2020). This report develops key aspects for a strategy framework for the Circular economy of the country.

Further west, Germany also showed no cointegration in this study. The major sectors presented in GDP are services sector (74,3%) and industry (24,2%), and through the years the country have been performing a good environmental path.

In 2021 , Germany was still heavily dependent on fossil fuels , meaning 28% was generated by using lignite and hard coal, and natural gas represented 15.4%. Although registered 39,7% of renewable energy sector, with the wind being the most prominent in the results.

As stated by Frondel et al. (2004) most environmental problems in Germany appear in the industrial sector due to use of natural resources and water or solid waste, and of course requires a more concern about this sector. Once the service sector represent the major contribution for the GDP in the country but the industrial sector is the main concern when analysing the environment, decoupling the variables could be a factor that could vary the result of the cointegration of fiscal policy, when analysing the model with the different sectors.

Although being the first in the European rank of CO<sub>2</sub> emissions, according to OECD Statistics, was registered a decline in 2020 in GHG emissions (compared to 1990) and was implemented in 2021 by the German government a target for 2030 of reducing the emissions by 65%.



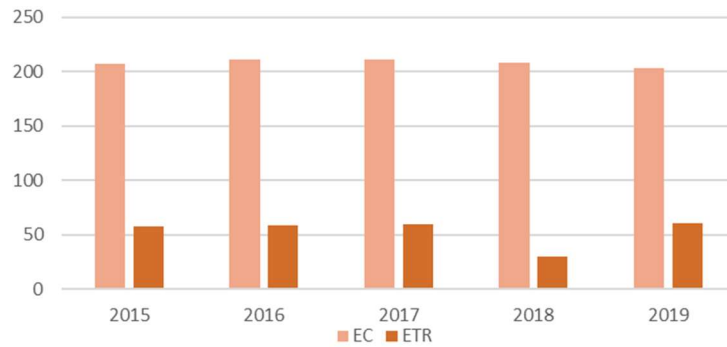
Note: 2021 not available for Greenhouse gas emissions in Germany

**Figure 2:** German total Greenhouse Gas Emissions (kT of CO<sub>2</sub> equivalent) (Source: World bank/OECD)

In 2021, German environmental taxes hit the record of low taxes, meaning that the environmental revenues are not covering all the cost, only a fraction of the environmental costs, as shown in figure 3. As a share of GDP, Germany presents one of the lowest shares of environment revenue in the GDP among the countries of OECD and 5 economies partners, being placed 19<sup>th</sup> on the respective rank. The major environmental tax registered in Germany is energy related (64%, according to Destatis, 2021), representing in 2021 a

total of 57.2 billion euros, being placed 12<sup>th</sup> on the energy tax rank of OECD across the 34 OECD countries and 7 partner economies.

Although GHG emissions are decreasing in Germany (Figure 2), the fiscal policy is not being sufficient once the costs of environment are being higher than the revenue achieved from the environment fiscal policy.



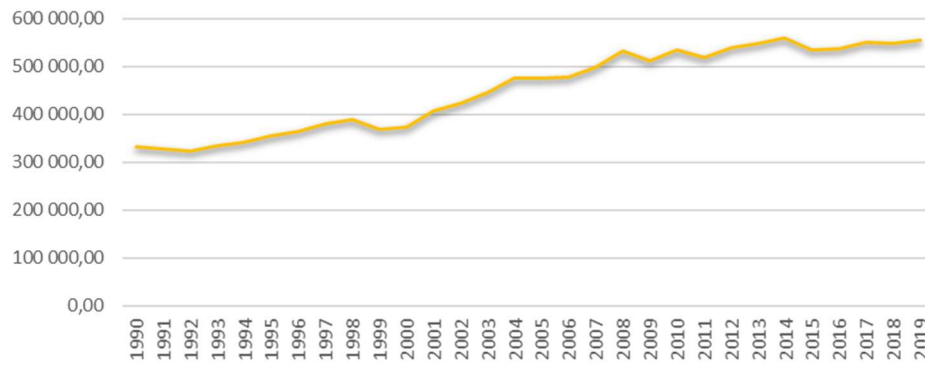
Note: Information not available for 2020 and 2021

**Figure 3:** German Environmental Cost and Environmental Tax Revenue (€ Billions) (Source: German Environment Agency, 2020)

South Africa occupies the 39<sup>o</sup> position in the ranking of CCPI. The country plays a crucial work in the energy sector, as a major exporter of electricity for the African continent. Is Considered one of the most vulnerable countries in the world in terms of Environment, having an annual temperature increasing every year by 1.5 times the observe global average (He et al., 2021). In 2006, was performed the Environmental Fiscal Reform (EFR) and taxes are in place for carbon and nitrogen oxide emissions.

The south Africa GDP is composed by 27.9% of industrial sector and 67.5% by the service sector, and fossil fuels are a big component for the South African revenue. The energy mix of South Africa in 2021 was composed by 3,41% of renewable energy and the major percentage is linked with fossil energy.

The country has the 31<sup>st</sup> highest tax rate on energy, and through taxes the government was able to collect in 2020, 6.95 billion USD. Although, when analysing the consequence of fossil fuels in the society, these consequences are higher than the revenue generated from taxes. To highlight, that the carbon tax was only implemented in June 2019.



Note: 2020 and 2021 not available for South Africa

**Figure 4:** South Africa total Greenhouse gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

Despite, being one of the countries with higher tax rates on energy, values of GHG have not reduced substantially (figure 4), not having a constant reduction, varying from year to year, indicating that fiscal policy, although high, is not having the expected effect. The service sector plays an important role in the country, being the major contributor for employment and economic growth generator. Being the use of fossil fuels more linked with the industrial sector, the decoupling of sectors in the model could modify the results, especially for the cointegration between service sectors and fiscal policy index.

The next country studied in this study with no cointegration was Poland, the 3<sup>rd</sup>-biggest country emitter of CO<sub>2</sub> in the European country, according to source Statistic, 2021.

The GDP is composed by 29.3% of the industry sector and 55.61% from the service sector. The energy mix is composed by 6.75% of renewable energy and 93.25% from fossil energy. Poland ranks 52<sup>nd</sup> in the CCPI ranking, less favourable, and most of which caused by the bad ranking in the GHG emissions. Environmental fiscal policy in Poland is mostly reflected on transport fuels and ranks the 25<sup>th</sup> place across OCDE countries and 7 partner economies, on the highest tax rate on energy. Although Poland is performing a positive path in the GHG emission as shown by the trend of the figure 5, Poland is still one of the most fossil fuel-reliant economy in the European union and in 2019, Poland's government implemented a strategy for the country, 2030 National Environmental Policy (PEP2030), of 30% of GHG reduction until 2030 (compared with 1990 levels). Carbon tax was implemented in 1990, although is taxing only 4% of the greenhouse emissions, as recent studies revealed in 2022.

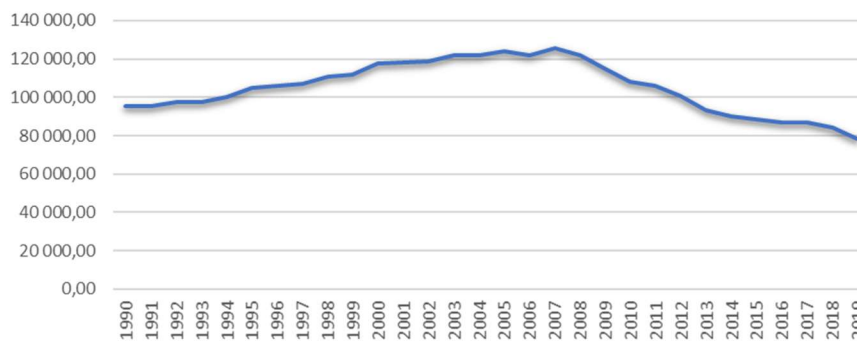


Note: 2020 and 2021 not available for Poland

**Figure 5:** Poland total Greenhouse gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

Greece ranks the 24<sup>th</sup> position in the CCPI ranking, which is a medium performance position and is one of the countries with higher tax rates related to environment in the European Union. In 2021, the GDP was composed by 15.95% from the industry and 67.49% from the service sector. The energy mix is composed by 21% of renewable energy.

In Greece, energy activities represent on average 76% of the total greenhouse emissions every year (Rapanos et al., 2005) and the tax revenues from environment represent 2,79% of GDP, higher than the average of OCDE, 2,0%, as released by the World bank on the carbon pricing dashboard, 2021. Despite having a positive trend over the years (as shown in figure 6), Greece is now acting to enhance the eco-innovation, through the implementation of circular economy.

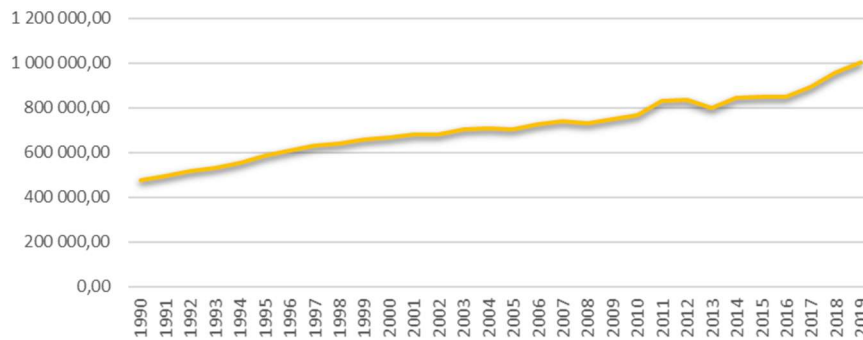


Note: 2020 and 2021 not available for Greece

**Figure 6:** Greece Total Greenhouse Gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

Indonesia ranks 27<sup>th</sup> in the ranking of CCPI, not so favourable, and the main reason is due to deforestation activities. The energy mix is composed by 92% of fossil energy and the GDP in 2021 was mainly contributed by the manufacturing sector (19.25%) and agriculture sector (13.28%).

The result in this study is in line with the reality of Indonesia. The correlation is null for fiscal policy and greenhouse emissions once only few taxes are created in Indonesia. Carbon tax is a powerful and effective policy, although is not implemented for Indonesia, and for energy tax related, Indonesia ranks the 3<sup>rd</sup> lowest tax rate when compared with OECD countries and more 7 partner economies.



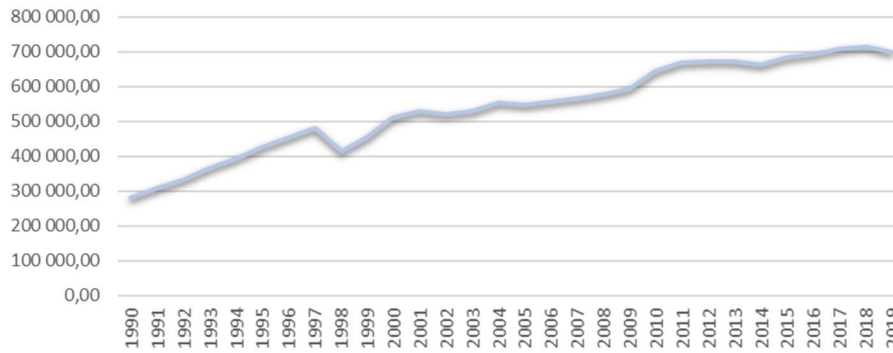
Note: 2020 and 2021 not available for Indonesia

**Figure 7:** Indonesia total Greenhouse gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

As shown by Robbi et al. (2019), through a econometric model with different variables such as trade openness, population, energy consumption and income per capita , showed that separating the sectors by size, like large and medium, is possible to conclude that environmental taxes are correlated and needed for large industries that don't use environmental friendly technology and medium industry.

In order to reduce the increase of GHG that have been increasing over time (figure 7), the president of Indonesia established a target for the country of a 26% reduction of greenhouse emissions until 2030.

Finally, Korea ranks 60<sup>th</sup> in the CCPI, considerably low position, registering a very low rate for GHG emissions in the ranking, and explained by the figure 8. The country does not have a carbon tax implemented although levy's an emission trading system. In 2021, the energy sector represented 86,9% of South Korea total GHG emissions, as released by Enerdata Statistic in 2021. The energy sector is composed by 98.4% of fossil fuel energy. Despite a trend path of GHG increase as shown in figure (8), Korea is committed to reduce by 30% the GHG emissions until 2030 (compared to 2018) and reduce until 2050 to a net zero emissions rate.



Note: 2020 and 2021 not available for Republic of Korea

**Figure 8:** Republic of Korea total greenhouse gas emissions (kt of CO2 equivalent) (Source: Worldbank/OECD)

Relative to the 22 countries with long-term cointegration, is important to stand out the countries with higher score in the CCPI ranking which were case study for this analysis, such as, Denmark and Sweden; and the result of 2 of the top 3 countries with higher greenhouse emissions, United States of America, and India.<sup>4</sup> The results for the cointegration encompasses both developing and developed countries.

The United States of America is an oil-based economy and registered a total value of greenhouse emissions of 5.981 million kt of CO<sub>2</sub> equivalent and is considered in a low position, 55<sup>th</sup> position, in the CCPI rank. With the old administration, President Donald Trump, the tax revenue as percentage of GDP was lower than the average of OECD countries. However, with the change in the organization, with the new president Joe Biden, the United States re-joined the Paris Agreement that was a vital step and showed a clear awareness of climate damage. In 2020, with the new president of the USA we faced a decrease in the GHG emissions, as expressed in figure 9.

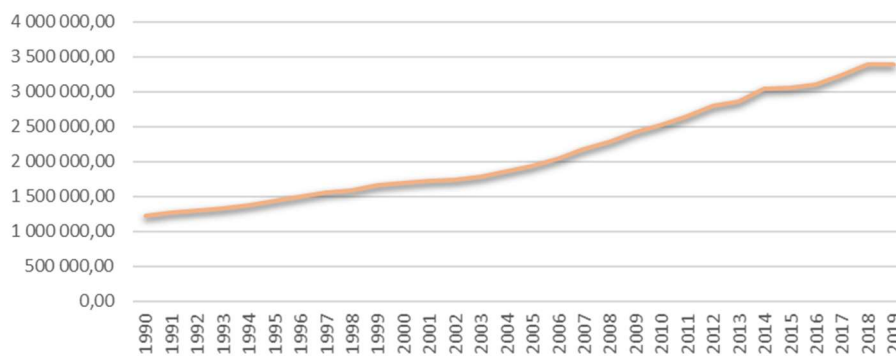


Note: 2021 not available for USA

**Figure 9:** USA greenhouse gas emissions (kt of CO2 equivalent) (Source: Worldbank/OECD)

<sup>4</sup> The top three countries with higher GHG emissions worldwide are: China, the United States, and India according to OECD, 2021.

India holds the 10<sup>th</sup> position in the CCPI rank, although when compared to the 34 OECD nations and five partner economies, it's considered the 4<sup>th</sup> lowest when analysing environmental tax revenue. Energy tax revenue was registered as 50% of the total revenue from environmental taxes, as released by OECD in 2021. Although this scenario, India improved the green path through renewable energy policies, such as implementing targets of renewable capacity and electric vehicle share by 2030. The green tax also known as Environmental Compensation charge imposed in India in the recent year, is a new path for the country by imposing a tax relative to vehicles, imposed on vehicles depending on the respective size.



Note: 2020 and 2021 not available for India

Figure 10: India greenhouse gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

Regarding the European Union countries selected in the sample that presented cointegration, 7 are in the top 30 of the rank, such as Denmark, Finland, Portugal, France, Netherlands, Sweden and Italy. The others European countries present lower levels in the rank, such as Austria, Belgium, Hungary, Ireland and Slovakia, although present interim positions.

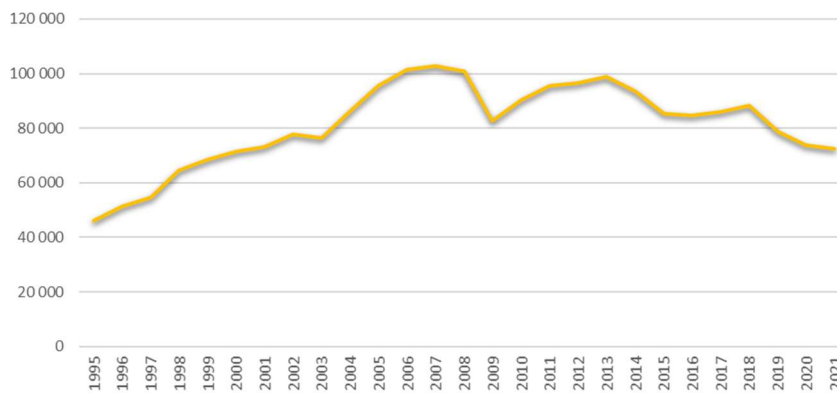
The results for European countries are in line with the current situation, once the measures for environment are becoming more present over time, in 2020 the total environmental tax revenue was €300.5 billion, according to Eurostat (2021), representing 2.2% of the total EU GDP, thus, the main source of energy taxes. Nevertheless, to highlight that relative to GDP this value decrease when compared to 2002 from 2.6% to 2.2%. Although United Kingdom left European Union in the recent years, the fiscal policies for environment were implemented through the years, and registered a carbon tax since 2013, having covered 21% of total greenhouse emissions in 2022, as study revealed, in carbon Pricing dashboard, by Worldbank.

Denmark ranked the highest position in the CCPI ranking and with one of the heaviest environment tax systems in the world is a pioneering example of environmental tax policies.

Denmark was a pioneer by introducing a carbon tax in 1992 on consumers and in 1996 for the business sector, and registers one of the highest GDPs in the world, being based on service industries. The carbon tax covered 35% of total greenhouse emissions, as study revealed in 2022, in carbon Pricing dashboard, by Worldbank.

The GHG emission in Denmark come especially from production of energy, agriculture, and transportation, counting as 75% of the total GHG emissions.

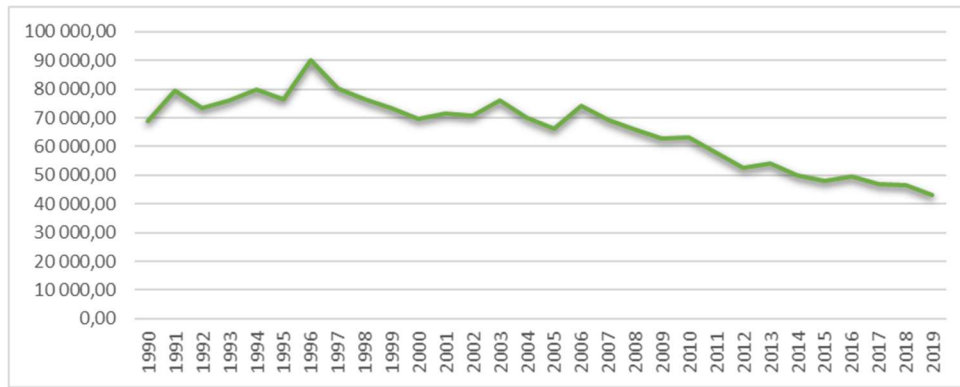
Since the 90's, Denmark government has been implementing successfully fiscal policies to reduce the GHG emissions (figure 11), being a long-time leader in the Environmental Tax reform. As such, Denmark is a successful example of environmental taxes, such as, the carbon tax in 1990 to households, the water, which was implemented in 1994, to reduce the water waste in the country, and car taxes that were implemented in 2007, which are small taxes when the car is energy efficient and expensive when the car is less efficient.



Note: no data available for 1990-1994

**Figure 11:** Denmark Environmental Taxes (Unit:m DKK) (Source: Statistics Denmark)

In 2021, Denmark registered a total value of environmental taxes of 72.329 m DKK, represented by 60.18% from households and 39,70% from the industrial sector, according to Statistic Sweden source. Since 1990 the country has a negative trend when analyzing the GHG emissions (figure 12).



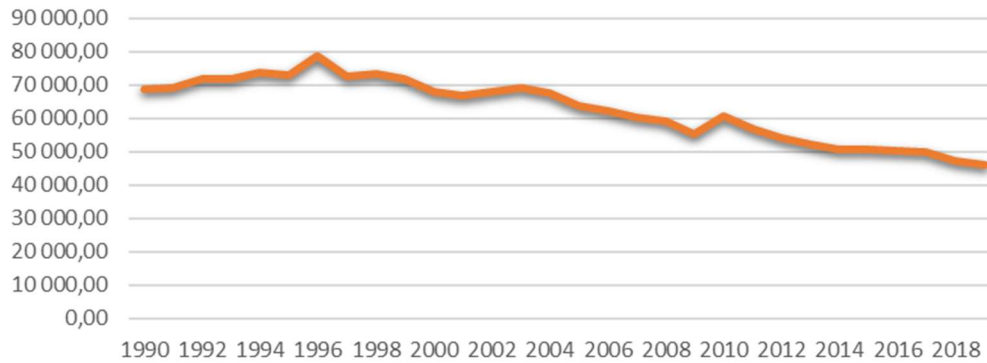
Note: 2020 and 2021 not available for Republic of Korea

**Figure 122:** Denmark total greenhouse gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

The Energy and Industry Agreement signed in 2020 between government and parties, is the new agreement for the green tax reform in the country. One of the major measures is the increase of fuel tax for industrial sector in 2023 and is accompanied by compensation measures for the respective sector. At the same time, there is the major goal of a uniform carbon tax, so that there is less incentive to consume and produce goods with high carbon content.

Another European country with a relevant position in the CCPI rank is Sweden, registering the second highest position. Environmental taxes represented in 2021 2% of total Swedish GDP, registering since 1993 a growth in environmental tax revenue, according to Statistic Sweden source and a decrease in GHG (figure 13) The major contributor for environmental tax revenue is the energy tax, contributing a total value of 75% in the total environmental tax revenue. The carbon tax was implemented in 1991, being also a pioneer, and according to the last studies applied in 2022 the carbon tax covered 40% of greenhouse emissions, according to Carbon Pricing Dashboard, by Worldbank (2022).

Having a long-time environmental policy, the Swedish government established new key goals for 2045, by establishing fossil-free dependency and 100% of renewable energy in the country.



Note: 2019,2020 and 2021 not available for Republic of Korea

**Figure 133:** Sweden total Greenhouse gas emissions (kt of CO<sub>2</sub> equivalent) (Source: Worldbank/OECD)

## Conclusion

The main objective of this thesis was to test fiscal policy in relation to environmental degradation, through a long run cointegration study between a fiscal policy index and greenhouse emissions. To perform the analysis, a fiscal policy index was estimated through a principal component analysis, based on tax revenues and government expenditures. The ARDL model was then used for each country, and the error correction mechanism was determined. The cointegration tests were carried out for each country, where it was concluded that among the 29 sample countries, there are seven where no cointegration exists between fiscal policy and environmental degradation measured by greenhouse emissions and 22 countries where a long run cointegration relation exists.

For the countries with no long run cointegration the economy of such country was highly dependent on energy consumption, having a big percentage of energy sector in the GDP of the respective countries. Although there are some environmental policies in these countries, they are not being effective and have some gaps in the system, such as low levels of fiscal policy, as in the case of Germany, the absence or late implementation of carbon taxes as in the case of South Africa (only implemented in June 2019), Indonesia, Czech Republic, Korea, Greece and Poland (although implemented in 1990 represent only 4% of total greenhouse emissions). This study suggest that a reform of the environmental fiscal policies would be a solution for the sample with no cointegration.

Therefore, it was also possible to conclude that fiscal policy is a core instrument for the major countries in the sample and global carbon taxes can be one of the most powerful and efficient way, as stated by the IMF's Fiscal Monitor of 2019.<sup>5</sup>

Through the sample of countries that registered cointegration, it was also possible to conclude that GHG emission depend on the major sectors of the countries and that fiscal policies are having an impact on balancing the greenhouse emissions.

Therefore, and as referenced by the IMF (2019), the fiscal policies need to step up the global ambition because the goals achieved so far are not enough to save environment.

The design of the current study is subject to limitations, as for example the time span, that was a small period selection (1990-2021), and although we decided to apply the ARDL model, to take care of this limitation and be more robust, not all data was available for the period selected for all countries turning our analysis with some limitations.

Future research could consider the possibility of a global fiscal policy reform in order to reduce greenhouse emissions, for example trough the study of the impact of a global carbon tax in the economy and increasing the countries of the sample.

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<sup>5</sup> Source: Fiscal Monitor – How to mitigate Climate change-FMI., 2019

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Appendices

Appendix 1. ARDL Model

| Country        |             | LGHG(-1)  | LGHG(-2)  | LEC       | LEC(-1)   | LEC(-2)   | LGDP      | LGDP(-1)  | LGDP(-2)  | FPI       | FPI(-1)   | FPI(-2)   | FPI^2     | FPI(-1)^2 | FPI(-2)^2 | C          |
|----------------|-------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| Australia      | coefficient | 0.360926  | 0.382682  | -0.201767 |           |           | -0.519773 | 0.622586  |           | 0.060402  |           |           | -0.012118 |           |           | 1.380194   |
|                | p-value     | 0.0084    | 0.0074    | 0.2646    |           |           | 0.0361    | 0.0101    |           | 0.0745    |           |           | 0.1579    |           |           | 0.2259     |
| Austria        | coefficient | 0.396333  | -0.201492 | 0.932836  |           |           | 0.134078  |           |           | -0.062063 |           |           | 0.026889  | -0.129912 | 0.096756  | 0.068622   |
|                | p-value     | 0.0110    | 0.1852    | 0.0001    |           |           | 0.5834    |           |           | 0.4261    |           |           | 0.4558    | 0.0100    | 0.0189    | 0.9895     |
| Belgium        | coefficient | -0.264096 |           | 0.648110  |           |           | -0.061363 | -0.415903 |           | -0.000126 |           |           | -0.003165 |           |           | 23.193220  |
|                | p-value     | 0.0678    |           | 0.0000    |           |           | 0.8276    | 0.1053    |           | 0.9966    |           |           | 0.3030    |           |           | 0.0000     |
| Canada         | coefficient | 0.196236  | -0.185356 | 0.286722  | 0.812807  | 0.775301  | 0.179616  | -0.848388 |           | 0.201847  |           |           | 0.028020  | -0.035764 |           | 13.832670  |
|                | p-value     | 0.3034    | 0.3057    | 0.4854    | 0.0351    | 0.0066    | 0.6311    | 0.0013    |           | 0.0313    |           |           | 0.2306    | 0.1177    |           | 0.0834     |
| Czech Republic | coefficient | 0.361181  |           | 0.877165  | -0.468097 |           | 0.138283  | 0.453151  | -0.384995 | -0.032620 | -0.058221 |           | 0.004265  |           |           | -0.980509  |
|                | p-value     | 0.0932    |           | 0.0004    | 0.0453    |           | 0.5885    | 0.2576    | 0.0950    | 0.6150    | 0.3030    |           | 0.5784    |           |           | 0.0789     |
| Denmark        | coefficient | 0.417842  |           | -0.310080 |           |           | 1.714631  | -1.254345 | 0.965266  | -0.001315 |           |           | -0.100183 | -0.121881 |           | -33.763560 |
|                | p-value     | 0.0121    |           | 0.1580    |           |           | 0.0086    | 0.1438    | 0.1457    | 0.9867    |           |           | 0.0420    | 0.0186    |           | 0.0136     |
| Finland        | coefficient | 0.561676  |           | 1.276297  | -1.243052 |           | 0.549315  |           |           | -0.289768 | -0.048552 | 0.222082  | 0.023911  | 0.050920  | -0.098319 | -9.431430  |
|                | p-value     | 0.0208    |           | 0.0005    | 0.0273    |           | 0.1731    |           |           | 0.0762    | 0.7356    | 0.0648    | 0.6269    | 0.4529    | 0.1041    | 0.2548     |
| France         | coefficient | 0.021770  |           | 0.661626  | -0.738905 |           | -0.226053 | 1.659259  | 1.380502  | 0.298351  | -0.830155 |           | -0.085171 | 0.118239  |           | -71.125150 |
|                | p-value     | 0.8994    |           | 0.1867    | 0.1291    |           | 0.6952    | 0.0371    | 0.0135    | 0.1925    | 0.0071    |           | 0.3280    | 0.2233    |           | 0.0005     |
| Germany        | coefficient | 0.853281  |           | 0.919101  | -0.838275 |           | -0.150683 |           |           | 0.043263  |           |           | -0.010238 |           |           | 5.608768   |
|                | p-value     | 0.0000    |           | 0.0000    | 0.0000    |           | 0.3349    |           |           | 0.4187    |           |           | 0.1863    |           |           | 0.1973     |
| Greece         | coefficient | 1.035227  |           | 0.024418  |           |           | -0.164608 |           |           | 0.140657  | -0.144653 |           | -0.013814 |           |           | -0.541086  |
|                | p-value     | 0.0000    |           | 0.8422    |           |           | 0.4263    |           |           | 0.0419    | 0.0343    |           | 0.2166    |           |           | 0.4323     |
| Hungary        | coefficient | 0.263795  |           | 0.801051  | -0.110961 | -0.118644 | -0.043533 |           |           | 0.068440  | 0.165760  |           | 0.006699  | -0.075641 |           | 6.257475   |
|                | p-value     | 0.1949    |           | 0.0000    | 0.6200    | 0.3134    | 0.0018    |           |           | 0.2791    | 0.0272    |           | 0.8251    | 0.0828    |           | 0.0006     |
| India          | coefficient | 0.323412  |           | 0.806551  |           |           | 0.016448  | 0.862656  | -1.056434 | -0.152981 | -0.586632 | 0.861927  | 0.042713  | 0.073283  | -0.184212 | 6.175972   |
|                | p-value     | 0.0625    |           | 0.0604    |           |           | 0.9708    | 0.1661    | 0.0343    | 0.6840    | 0.1817    | 0.0174    | 0.5833    | 0.5277    | 0.0436    | 0.1099     |
| Indonesia      | coefficient | 0.894259  |           | 0.552426  | -0.350072 |           | -0.074080 |           |           | 0.616043  | 0.185618  |           | -0.084129 | 0.096260  |           | 2.254429   |
|                | p-value     | 0.0000    |           | 0.0741    | 0.2443    |           | 0.3232    |           |           | 0.1485    | 0.1972    |           | 0.1687    | 0.1792    |           | 0.1441     |
| Ireland        | coefficient | 0.159266  | 0.362246  | 0.521517  | -0.296775 |           | -0.015817 | 0.086775  | 0.111338  | -0.059993 | 0.044791  | 0.060609  | 0.012564  | -0.035280 |           | 4.169289   |
|                | p-value     | 0.3869    | 0.0189    | 0.0003    | 0.0124    |           | 0.7965    | 0.1776    | 0.0465    | 0.5379    | 0.2140    | 0.1654    | 0.6376    | 0.2772    |           | 0.0007     |
| Italy          | coefficient | 0.487526  |           | 1.467459  | -0.997508 | 0.305829  | -0.530767 | 1.078066  |           | -0.320819 |           |           | 0.071295  |           |           | -16.575060 |
|                | p-value     | 0.0167    |           | 0.0000    | 0.0136    | 0.1778    | 0.1553    | 0.0053    |           | 0.0652    |           |           | 0.1048    |           |           | 0.0700     |
| Korea          | coefficient | 0.695620  |           | 0.889733  | -0.747296 |           | -0.734336 |           |           | 0.852847  | -0.769963 |           | -0.153032 | 0.148830  |           | 1.042368   |
|                | p-value     | 0.0004    |           | 0.2466    | 0.3093    |           | 0.4541    |           |           | 0.1433    | 0.1741    |           | 0.1847    | 0.2051    |           | 0.7863     |
| Mexico         | coefficient | 0.252601  |           | -1.204417 | 0.932557  | 0.644581  | 0.351166  | 0.333549  | -0.613726 | 0.151566  |           |           | -0.031258 | -0.005075 |           | 3.100974   |
|                | p-value     | 0.2598    |           | 0.0040    | 0.1677    | 0.2042    | 0.0931    | 0.1797    | 0.0163    | 0.6785    |           |           | 0.7198    | 0.9589    |           | 0.1930     |
| Netherlands    | coefficient | 0.690475  |           | 1.403492  |           |           | -0.356318 |           |           | 0.075469  | -0.348561 |           | 0.009282  |           |           | 1.656823   |
|                | p-value     | 0.0001    |           | 0.0023    |           |           | 0.0116    |           |           | 0.6581    | 0.0590    |           | 0.5476    |           |           | 0.6059     |
| Norway         | coefficient | 0.565714  | -0.279996 | 0.408903  |           |           | 2.682581  | -1.588831 | 1.663391  | -1.555363 |           |           | 0.084458  | 0.286070  | -0.249036 | -74.130650 |
|                | p-value     | 0.0181    | 0.1523    | 0.4707    |           |           | 0.1084    | 0.1124    | 0.0400    | 0.0815    |           |           | 0.5440    | 0.0411    | 0.0370    | 0.0948     |
| Poland         | coefficient | 0.360190  |           | -0.008029 | -0.523477 |           | 0.206261  |           |           | 0.085133  |           |           | 0.000090  |           |           | 2.584477   |
|                | p-value     | 0.0624    |           | 0.9773    | 0.0951    |           | 0.0040    |           |           | 0.3645    |           |           | 0.9845    |           |           | 0.0502     |
| Portugal       | coefficient | 0.086040  |           | 0.018211  | 0.362985  | 0.385770  | 0.893108  | -0.369922 | -0.342399 | -0.103827 |           |           | 0.046546  | -0.058421 |           | 1.224117   |
|                | p-value     | 0.6913    |           | 0.9333    | 0.1519    | 0.1316    | 0.0555    | 0.5353    | 0.3440    | 0.0274    |           |           | 0.1939    | 0.1291    |           | 0.7433     |
| Russia         | coefficient | 0.243550  |           | 0.658335  |           |           | 0.032479  |           |           | 0.028766  | -0.050637 |           | -0.006390 | 0.018536  |           | 4.135546   |
|                | p-value     | 0.0343    |           | 0.0086    |           |           | 0.1790    |           |           | 0.1803    | 0.0077    |           | 0.2917    | 0.0073    |           | 0.0386     |
| Slovakia       | coefficient | 0.299126  | 0.336137  | 0.696608  |           |           | -0.199437 | -0.212164 | -0.342242 | 0.119570  | 0.115435  | 0.076896  | -0.057615 | -0.041429 | 0.052003  | 18.871810  |
|                | p-value     | 0.0413    | 0.0312    | 0.0003    |           |           | 0.2512    | 0.2502    | 0.0295    | 0.0402    | 0.0843    | 0.1493    | 0.0183    | 0.0945    | 0.0541    | 0.0003     |
| South Africa   | coefficient | 0.634768  |           | 0.316738  | -0.300943 |           | 0.045684  |           |           | 0.005077  |           |           | -0.004013 |           |           | 2.357372   |
|                | p-value     | 0.0005    |           | 0.0573    | 0.0675    |           | 0.2636    |           |           | 0.9402    |           |           | 0.1695    |           |           | 0.0177     |
| Sweden         | coefficient | 0.836854  | -0.531541 | 0.028587  |           |           | -1.456590 | -0.702456 | 1.634894  | 0.314318  |           |           | -0.057359 |           |           | 17.342670  |
|                | p-value     | 0.0002    | 0.0124    | 0.9506    |           |           | 0.1291    | 0.4547    | 0.0332    | 0.1919    |           |           | 0.0485    |           |           | 0.3260     |
| Switzerland    | coefficient | 0.145911  |           | 0.059275  |           |           | 0.194026  | -0.196453 | 0.600953  | 0.140892  | 0.047528  | -0.282447 | -0.079018 | -0.069017 | 0.117634  | -7.103230  |
|                | p-value     | 0.4626    |           | 0.6728    |           |           | 0.5711    | 0.6715    | 0.1180    | 0.2249    | 0.6218    | 0.0152    | 0.1431    | 0.1125    | 0.0337    | 0.4559     |
| Turkey         | coefficient | -0.000229 |           | 0.716659  |           |           | -0.006935 |           |           | -0.160679 | 0.458461  |           | 0.091675  | -0.145859 |           | 7.859541   |
|                | p-value     | 0.9992    |           | 0.0007    |           |           | 0.6401    |           |           | 0.7091    | 0.0619    |           | 0.2751    | 0.1710    |           | 0.0111     |
| United Kingdom | coefficient | 1.120983  | -0.473651 | 0.340312  |           |           | 0.257301  | -0.646537 | 0.999259  | -0.070393 | -0.333573 |           | -0.023904 | 0.222068  | -0.158745 | -16.069120 |
|                | p-value     | 0.0000    | 0.0184    | 0.3935    |           |           | 0.4915    | 0.2341    | 0.0162    | 0.8172    | 0.2703    |           | 0.8165    | 0.0801    | 0.0122    | 0.0388     |
| United States  | coefficient | 1.117223  | -0.531639 | 0.379246  | 0.400575  | -1.291293 | 1.354436  | -2.881778 | 1.598516  | -0.118954 | 0.380081  | -0.209132 | 0.016374  | -0.080085 | 0.076881  | 8.216175   |
|                | p-value     | 0.0000    | 0.0289    | 0.4246    | 0.3940    | 0.0022    | 0.0512    | 0.0104    | 0.0630    | 0.3509    | 0.0361    | 0.2115    | 0.6436    | 0.0715    | 0.0718    | 0.0311     |

**Appendix 2. ECM coefficient Adjustment**

|                | ECM coff Adjst. | P-Value |
|----------------|-----------------|---------|
| Australia      | -0.2564         | 0.0001  |
| Austria        | -0.8052         | 0.0000  |
| Belgium        | -0.2641         | 0.0000  |
| Canada         | -0.9891         | 0.0000  |
| Denmark        | -0.5643         | 0.0001  |
| Finland        | -0.3452         | 0.0005  |
| France         | -0.9707         | 0.0000  |
| Hungary        | -0.7362         | 0.0001  |
| India          | -0.6766         | 0.0001  |
| Ireland        | -0.4785         | 0.0001  |
| Italy          | -0.5125         | 0.0001  |
| Mexico         | -0.7474         | 0.0003  |
| Netherlands    | -0.3095         | 0.0001  |
| Norway         | -0.7143         | 0.0001  |
| Portugal       | -0.9140         | 0.0001  |
| Russia         | -0.7565         | 0.0004  |
| Slovakia       | -0.3647         | 0.0000  |
| Sweden         | -0.6947         | 0.0001  |
| Switzerland    | -0.8541         | 0.0043  |
| Turkey         | -0.3468         | 0.0056  |
| United Kingdom | -0.3527         | 0.0000  |
| United States  | -0.4144         | 0.0000  |

**Appendix 3. Model Stability**

| Country        | AUTOCORRELATION | HETEROSKEDASTICITY |
|----------------|-----------------|--------------------|
| Australia      | 0,727           | 0,580              |
| Austria        | 0,759           | 0,903              |
| Belgium        | 0,746           | 0,778              |
| Canada         | 0,119           | 0,161              |
| Czech Republic | 0,114           | 0,713              |
| Denmark        | 0,855           | 0,116              |
| Finland        | 0,586           | 0,695              |
| France         | 0,123           | 0,666              |
| Germany        | 0,619           | 0,406              |
| Greece         | 0,081           | 0,896              |
| Hungary        | 0,476           | 0,946              |
| India          | 0,450           | 0,833              |
| Indonesia      | 0,132           | 0,955              |
| Ireland        | 0,097           | 0,709              |
| Italy          | 0,715           | 0,074              |
| Korea          | 0,082           | 0,211              |
| Mexico         | 0,065           | 0,251              |
| Netherlands    | 0,667           | 0,686              |
| Norway         | 0,142           | 0,542              |
| Poland         | 0,550           | 0,076              |
| Portugal       | 0,133           | 0,884              |
| Russia         | 0,935           | 0,246              |
| Slovakia       | 0,278           | 0,253              |
| South Africa   | 0,195           | 0,136              |
| Sweden         | 0,066           | 0,392              |
| Switzerland    | 0,428           | 0,806              |
| Turkiye        | 0,320           | 0,383              |
| United Kingdom | 0,063           | 0,843              |
| United States  | 0,075           | 0,495              |

**Appendix 3. CUSUM Stability Test**

