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THE NEXUS BETWEEN GFCF, ENVIRONMENTAL TAX AND AIR POLLUTION EFFECTS IN EU-16 COUNTRIES.

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Abstract*:* The paper studies the impact of Environmental Tax (Etax), GDP, and air-pollution effects (APE) on the GFCF of EU-16 countries by taking the annual data from 1991-2020 through second-generation panel data analysis. All the variables are cross-sectionally dependent, differenced stationary, and cointegrated over the long term, according to the empirical estimations. Additionally, it is discovered that GFCF and GDP have a positive relationship. Moreover, the environmental tax is estimated to be negatively related with GFCF in EU-16 countries.

Keywords: Environmental Degradation, Economic Growth, Environmental Tax, Air-Pollution Effects, and Second-Generation Panel Data Analysis.

JEL Code: C51, O13, Q01, Q54

1. Introduction

The natural consequences of the increasing economic activities that led to the adoption and imposition of the environmentally responsible economic growth policies were always the constantly shifting climate and the rising level of global competitiveness. These policy objectives motivate scientists to research and employ the most efficient use of resources throughout production to reduce environmental effects. Recent developments in "the literature show the consequences of environmental taxes on economic growth and investment spending", considering the effects of air pollution as well. The results of "the study on the negative impacts of air pollution on the environment advised that no economy's economic development should be kept a secret". The development of these nations' economy is mostly being driven by their investment spending (Shaikh, 2020). The "nexus of gross fixed capital formation is defined by the adoption of various technologies".

Due to its potential and improved coordination to reduce the issue of carbon emission, recent advancements in the literature of environmental policy and tax policy have attracted the attention of economists and policy makers. (Goulder & Parry, 2020). To determine whether GDP and Environmental Tax (ET) have had any appreciable effects on the degree of air pollution effects and the complementing phenomenon of GFCF among the 16 chosen countries of the European Union, this study focuses on potential solutions to this problem. The problematic usage of Environmental Tax across the EU has been made simpler by the voluntary targets set by EU members over the past ten years for the reduction of air pollution and advancement in GFCF. The fundamental idea behind environmental taxes is that they serve as a tool for achieving long-term environmental objectives. The primary issue and cause of environmental pollution is when the parties that polluted did not have to bear any financial responsibility for their activities. Since the outset, conventional practices have been utilized to battle and maintain the standard emission level, including regulatory mechanisms with implications for policies (Popp et al, 2010).

The 16 developed nations of European Union that make up GDP of EU are the subject of this study, and they are not the exception in that respect. To achieve the goals of green reform policies, a suitable utilization of gross fixed capital formation should be required.

The EU has set a goal to reduce the GHG emission to 40% by 2030 and around 80-90% in 2050 (Com, 2011: EU, 2014). The first step in the direction of sustainable economic development is to properly channel future investment. As evidenced by the developed economies' declining EKC curve, environmental tax programs are more effective in developed nations. The continued unchecked production demand and supply chain in developing countries, in sectors that appear to be economically inefficient, is the reason environmental tax policy functions better in developed countries. Taxes are uniform for all businesses, which causes the difference in marginal cost with no further technological innovation in pollution technologies (Cole & Grossman, 1999). Thus, it acts as a hindrance in the economic development of developing countries.

Environmental taxes have a significant impact on how new technologies are adopted and how fixed capital creation is channeled in industrialized nations with both uniformity and economic efficiency in the industrial and service sectors. According to the recommendations of environmental policy experts, taxing the energy-inefficient and non-renewable energy-consuming companies and services is urgently needed. In conclusion, strict taxation measures must be implemented in industrialized nations to discourage environmentally harmful activity. The effects of air pollution also appear to be rising steadily in terms of human health and geographic damage, on the other side. To actively avoid the deliberate effort of environmental damage, it is also necessary to evaluate the impacts of investment spending on air pollution. Additionally, these tools are quite beneficial and offer long-term support in the form of incentives, tax breaks, and primarily technological innovation and pollution reduction. (Du et al., 2019). Neglecting the Paris Summit Agreement by the USA (Shaikh, 2021) is a major setback in framing the environmental policies and implementing them. Therefore, such studies are important to highlight the importance of climate change.

In sum, this paper is considering investigating the impact of economic growth (real GDP), environmental tax (Etax), and air-pollution effects (APE) on the gross fixed capital formation (GFCF) or the future expenditures.

2. Theoretical Background and Literature Review

This section of this paper provides the theoretical background related with environmental tax, air-pollution, and economic growth in general. Moreover, this section will also describe the previous rigorous research works in this field.

2.1. Theoretical Framework

Here, we give a summary of the conceptual framework that will be applied to the development of the econometric model and that is crucial in determining which variables to use for this investigation. Environmental taxes have been shown to be an effective policymaking criterion for "reducing greenhouse gas emissions"(Gaith & Epplin, 2017: Bashir et. al, 2020). Environmental tax changes have been found to negatively affect CO2 emissions. (Sundar et. al, 2016), as "carbon emissions are the main cause of greenhouse gas emissions" (Hammar & Sjostrom, 2011). While several research (Meng et. al, 2013: Niu et al., 2018: Li et al., 2022) have shown how effective environmental taxes are, others like (Lin & Li, 2011) have suggested that "ET only have a small impact on greenhouse gas emissions".

Miceikiene et. al. (2018) when technical innovation in "the energy and environmental sectors is prioritized, environmental taxes are most successful at improving environmental quality, according to research on the subject". Studies on "the connection between environmental technology and carbon dioxide emissions are becoming more prevalent and can be broadly divided into two areas.: 1) how environmental technology helps in carbon emissions reduction and 2) how it supports cleaner sources of energy".

According to (Du et al, 2019), who looked at "the technological innovations contribution to carbon dioxide emissions and innovation in environmental technology considerably reduces carbon emissions". Du & Li (2017) suggested that "environmental technologies reduce carbon emissions because the positive impact of environmental advances in technical sectors reduces environmental contamination".

By analyzing Mediterranean economies from 1990 to 2016, (Kahouli, 2018) "concluded that there is a negative correlation between technological development investments and carbon dioxide emissions". The conclusion "that environmental technology advancements are preventing environmental degradation is supported by the fact that the analyzed nations have vigorously promoted R&D investment in green technology to reduce greenhouse gas emissions. In their examination of the circumstances in the United States, China, and the European Union (Fernandez et al., 2018) claimed that while R&D funding in the US and EU was crucial for lowering carbon emissions, China's economy" would suffer as a result. Additionally, according to these writers, spending on environmental technology and investments can realistically help to lower carbon emissions. The fundamental economic objective remains the achievement of a set growth rate, making GDP growth one of the crucial macroeconomic indicators in the creation of a country's strategy. However, it is impossible to disregard the effects of environmental deterioration. As a result, in recent years, policymakers and academics have been interested in the relationship between future investments growth; gross fixed capital formation with environmental taxation as a major tool to curb the environmental degradation.

Based on "the literature review above and the theoretical framework, we can descriptively, write our model to evaluate the long run association between gross investments or gross fixed capital formation (GFCF) as a function of economic growth (GDP), environmental tax (ET) and air pollution effect (APE)" in the following manner.

$$GFCF = f\,(GDP, ET, APE) \qquad (1)$$

Where, GFCF is our dependent variable, whereas GDP, ET, and APE are our explanatory or independent variables.

The important explanatory variables taken for our model are discussed below:

2.1.1. Environmental Taxes

The recent development in the EU environmental tax revenue comes from energy sector 77.2%, transportation 19.1% and portion of "taxes on pollution and resources is only 3.75, which very small in comparison to other tax revenue represent 2.2% of EU GDP and 5.4% of total EU governments" revenue from taxes contributions (World Bank, 2020).

Pigou (1920) claims that "the ideal environmental tax is one that strikes a balance between the marginal private benefit of emissions in production and the marginal social damage of emissions". Environmental taxes are defined by international organizations as "a tax whose tax base is a physical unit (or a proxy of it) that has a proven specific negative impact on the environment" (UN, 2021). The United Nations definition, which is endorsed by the major international organizations including the OECD and the Statistical Office of the European Union, served as the foundation for the measure of environmental tax income used in this study. In the OECD's statistics on environmental taxes, taxes on energy goods such fossil fuels, electricity, and transportation fuel are included (petrol and diesel). All CO2-related taxes are included in this. The data on environmental tax income also includes motor vehicle and transport taxes, which include one-time import or sales taxes on transportation equipment, ongoing taxes on the ownership, registration, or use of motor vehicles on public roadways, as well as other transport-related taxes (excluding transport fuel taxes).

In 2016, the OECD has added more details regarding four different types of environmental tax revenue. These include "(i) taxes on ozone-depleting substances like dichloromethane and nitrogen oxides (CFCs); (ii) taxes on water and wastewater like those on water extraction, piped water, and wastewater treatment; (iii) taxes on waste management like those on the final disposal of solid waste and on packaging (like plastic bags); and (iv) taxes on mining and quarrying like mining royalties and excavation taxes (e.g., sand and gravel)". Other taxes were used to classify the remaining environmental tax revenue, which includes taxes on hunting, fishing, SO2 emissions, and NO2 emissions (Hassan et al, 2020).Thus, We used the total revenue from all environmental taxes as a proportion of GDP, which was derived from the OECD database, to analyze the relationship between environmental taxes and the pace of economic growth and the impacts of air pollution.

2.1.2. Air Pollution Effects

According to the OECD, breathing in "tiny particulate matter (PM2.5) can cause major health problems, including respiratory and cardiovascular disease, and is particularly risky for children and the elderly". It has been established that exposure to PM2.5 greatly increases the risk of heart disease, including stroke. Premature death costs are the only costs included in cost forecasts. The "Value of a Statistical Life" (VSL) and the quantity of premature deaths related to ambient particulate matter are established and employed to determine the effects of air pollution (OECD, 2020).

The main issues brought on by air pollution are the dramatic changes in climate, acidification, eutrophication, urban air quality, decreasing level of ozone, quality of human development index, rising mortality rate, physiological changes in the human body, and rising death rate (Ipek, 2022). Which of the century's oldest social and environmental issues has had devastating results the other way around. The rise of the industrial revolution and urbanization are primarily blamed for the degree of air pollution (Ortiz et al, 2020). The two primary types of pollutants that humans put into the air are anthropogenic and naturogenic due to the intricacy of air pollution. Due to the periodic change and association effects among the pollutants, identifying air pollution is challenging (Mauderly et al, 2009).

"GHG emissions, Ammonia (NH3), Nitrogen Oxide (NOx), Carbon Emission (CO2), Particulate Matter (PM), Sulfur Dioxide (SO2), Ozone, and Non-methane Volatile Organic Compound are the main pollutants defined by the European Union (NMVOCs)". Since the 1980s, every contaminant has been subject to stringent scrutiny. Numerous laws and legislative initiatives have been established to address pollutants that affect ambient air quality, primarily in the European Union, which is leading the world's group of nations in reducing greenhouse gas emissions from 15% to 8%. (Ortiz et al, 2020). The European Union has a total share of GFCF of 22% of total GDP for a green environment and to reduce emissions for good air quality with the total environmental tax revenue of 5.4% of GDP, only 72% of which comes from the energy sector, and the total GDP of EU member countries is approximately 23.4 trillion USD, making it the largest economy in the world (World Bank, 2021).

2.2. Literature Review

The preliminary research focusing on the behavior of environmental taxes regarding gross domestic product and industrial based air pollution effect globally, (Hassan et al, 2020) conducted research on 31-OECD countries using Correlation Random Effect (henceforth; CRE) a panel data approach over a period of 1994-2013. Their empirical findings indicated ET in high income level countries is increasing the initial level of GDP whereas the in countries with lower income level, the "GDP is negatively related to ET, both in long and in short run". Thus, "environmental taxes hypothesis is valid for high GDP level countries", in case of under-developed or developing countries ET can lead to shrink the economic growth due to the rise in price with increase in manufacturing and emissions. Moreover, the concept of ET is valid in those countries where service sector is more dominated than manufacturing sector due to the binding benefit of human capital in economic growth (Aloi & Tournemaine, 2011; Pautrel, 2009).

Safi et al, (2021) conducted research conducted on G7 countries validating the hypothesis of environmental taxes policy, over a period of 1990-2019. A panel data approach is employed which is known as "Cross-sectional Autoregressive Distribution Lag (Henceforth: CS-ARDL) with Common Correlated Effect Mean Group model (Henceforth: CCEMG)" by using variables, environmental related taxes, export, environmental-related R&D and consumption-based emission. Moreover, "the study also uses Granger Causality Test to check the direction of causation". The findings of this study validated the policy considering environmental related taxes with selected variables can significantly promote the reduction of carbon emission. Thus, it was denoted that the policy focusing on the promotion of environmental related tax could be the changing factor in developed countries as they do not have the problem of fluctuating economic growth due to their high level of human capital and concerns about the environmental quality.

Ghazouani et al. (2021) investigate the impact of ET and technologies on greenhouse emission in European countries over a period of 1994-2018. Fundamental estimation of the research covered under FMOLS & DOLS model. A panel data of greenhouse gas emission, environmental tax rate, renewable energy consumption, unemployment rate, and per capital gross domestic product growth rate was taken from world bank, OECD, and EIA. The empirical research has found the presence of "cross-section dependence in the panel data of all the variables". Also, the second-generation unit root test found all variables are differenced stationary. Moreover, the second generation cointegration tests indicated that variables are cointegrated in the long run. Generalized least square regression empirical estimates found that ET and REC have a negative relationship with greenhouse gas emissions. Statistically, 1% rise in ET and REC can decrease in greenhouse gas emission up to 0.146% and 0.11% respectively. Furthermore, both FMOLS & DOLS model estimated coefficients are found to be statistically significant which posited that ET and environmental quality overall are an effective tool to decrease carbon emission. Suggestion of the research directed towards effective policies of environmental taxes and renewable energy consumption, sustainable jobs can help in unemployment and sustainable development.

Bashir et al. (2020) conducted research on OECD countries over a period of 1995-2015 to empirically investigate the relationship between "ET and carbon emission with role of environmental technologies and FD by adopting the pool OLS and GMM and regression approaches". Data of the research variables, CO2, renewable energy, economic growth, ET, development of the technology, and financial development were obtained from the OECD. The empirical estimates of GMM model indicated that

ET and RE has a significant negative relationship with carbon emission in OECD countries for long run, FD has a negative relationship with CO2, ET considered to improve the environmental quality and level of human capital. Furthermore, OLS estimates outcomes indicated that economic growth has significant positive relationship with CO2, ET and CO2 significant negative relationship, where environmental technologies improve the environmental quality with significant negative value, financial development positive impact on emission improves the environmental quality results of the model were stable and significant. Thus, concluded that the technological innovations with investment can promote the sustainable economic development, considering the environmental quality and human capital can be improved through financial development and GFCF.

Degirmenci & Aydin (2021) investigated empirical research on several African countries over a period of 1994-2017, where panel data approach was analyzed by using AMG model. The "cross-section dependence and first difference stationarity were determined and the long run cointegration between the variables was found". The empirical result of model explained that ET is negatively affecting CO2 emission in long-run, meaning that with imposing of environmental taxes carbon emission is decreasing. The stability of the model was statistically significant. Hence, their suggestion directed the concern of the policy maker towards the control of degradation other than financial advancement in under developing countries as taken in the study are reliable. Also, as per the researcher suggestion, the environmental tax policies might be beneficial for developed and developing countries but under developing countries might face rise in unemployment and anthropogenic emission.

Niu et al. (2018) applied Bayesian dynamic approach to investigate the ET shock on CO2 emission on China by employing "dynamic Stochastic general equilibrium (henceforth, DSGE) model". Estimation result indicated that ET has a negative effect in CO2 reduction in China and can improve the energy intensity through consumption of renewable energy.

Abdullah & Morley (2014) research on "the nexus between environmental taxes and economics growth EU-25 and OECD countries for the period of 1995- 2006". They used a panel data approach for the variables, ET, GDP, tax on GDP, Ttax, ANS, DTax, GTax, RE by employing general approach of Granger non-causality test. Their Generalized method of moments (henceforth; GMM) method estimates indicated a long-term causality among the GDP and environmental taxes are positively related in EU-25 and OECD countries. Thus, the direction of the research pointed out towards the adoption of other variables and data. Therefore, it can be considered that the area and policy regarding ET and GDP needs to be advance by adopting the recent and latest explanatory variables to get the significant estimates. Subsequently, due to the lack of long data for China and USA indicates the significant estimates of the study. Capital formation in developed or developing countries might play an effective role in enhancing the environmental tax policies in improving the environmental quality.

Hashmi & Alam, (2019) conducted research on the role of environmental-friendly patent and taxes in promoting the sustainable green innovation and regulations in 29-OECD countries for the period of 1990-2014. A panel data approach was employed by using STIRPART, Fixed effect and GMM model empirical estimates for the variables, CO2, total population, GDP, NEP, and ET were employed. The empirical model outcome indicated that number of environmental patents is negative and significantly related to the carbon emission, GDP and POP is positively related to carbon emission. Thus, it was denoted that the collection of ET and environmental development are considered to be responsible for the better environmental quality in economic development.

Nchege & Okpalaoka (2022) conducted research to identify the relationship among GFCF and air pollution in Nigeria by employing the ARDL model approach for the year of 1985-2019. Empirical estimates of the research found the significant and positive relationship of air pollution with GFCF and GDP. Thus, increase in air pollution could be the outcome of growing economy with can be tackled by the adoption of environmental taxes and revenue spent in the direction of sustainable development goals.

Mujtaba & Shahzad, (2021) research on the implication of sustainable development policies in OECD countries over a period of 2002-2018 by employing a panel data empirical technique by adopting variables (Health, GDP, CO2, nitrogen oxide as air pollutant, education, and renewable energy) and FM-OLS and VECM model approach to estimate the coefficients. Empirical estimates of the research outlined that advancement of sustainable investment is negatively and significantly related to the air pollution, which can be denoted as adoption of sustainable investment policy can reduce the rising problem of pollution with the positive relation to economic growth. Therefore, GFCG in developed and developing economies is appearing as an effecting agent to combat the rising problem of air pollution and sustainable GDP.

He et al, (2021) "analyzed the heterogenous impact of environmental taxes on energy efficiency in OECD countries for the period of 1995-2016". The functional criteria of the research aimed to identify the impact of various taxes on energy efficiency with economic growth by employing panel ARDL model approach. The empirical estimates of the research indicated that energy efficiency is significantly related to the environmental taxes for long and short run in the OECD countries, which is significantly helping the condition of environment. Moreover, estimates of the ARDL panel approach also pointed out that the functional size of GDP does matter for environmental tax impact in energy efficiency and level of emission by adopting renewable energy. Thus, the research led us to explore the impact of environmental taxes on developed countries by following the different approach and latest explanatory variables.

Li et al, (2021) conducted research to check the impact of environmental tax impact on air pollution in China's plant over a period of 2017-2019. also found the positive relationships among environmental taxes and air pollution, which impacted positively on emission reduction in China. Also, GFCF in case of China is negatively related to air pollution effects (Khan et al, 2021).

Table 1. Summary of the Literature Review

Authors	Country	Period	Variables	Methodology	Conclusion
Hassan et al. (2012)	31-OECD	1994-2013	GDP, ET, TLF, LAED, EXP, Tax, FB, GFS, INF, CPI, OPENG	CRE	ET is Positively related to GDP in developed Economies
Safi et al. (2021)	G-7 Countries	1990-2019	ETs, Export, ER&D, CCE,	CSARDL, CCEMG	ET is Positively related to GDP, GFCF is Positively related to the environmental quality
Ghazouani et al. (2021)	EU	1994-2018	GHG, ET, RE, UNP, GDPC,	FMOLS, DOLS,	Negative relationship between ET and overall pollution
Bashir et al. (2020)	OECD	1995-2015	ET, EC, REC, ET, CO2, ETax, FD, DT	OLS, GMM	Negative ET with GDP Positive FD is Positively related with GDP, Environmental Quality
Degirmenci & Aydin (2021)	5 African Countries	1994-2017	CO2, UNP, ET,	AMG	Negative Relationship ET and economic growth, Positive FD, Environmental Quality,
Niu et al. (2018)	China	EPT law adopted in 2016	Bayesian E-E-E	DSGE	ET has a negative relationship with CO2 which helps improve in APE.
Abdullah & Morley (2014)	25-EU, OECD	1995-2006	GDP, ET, DTax, GTax, RE, ANS	ARDL, EPC,	ET positively related to GDP
Hashmi & Alam (2019)	29-OECD	1990-2014	CO2, GDP, POP, NEP, ET	GMM	ET positively related to GDP
Nchege & Okpalaoka (2022)	Nigeria	1985-2019	APE, GDP, GFCF, CO2,	ARDL	GFCF positively related to GDP
Mujtaba & Shahzad (2021)	28-OECD	2002-2018	Health, GDP, CO2, AP, EDU, RE,	FMOLS, VECM	AP is negatively related with CO2
He et al. (2021)	OECD	1995-2016	Energy Tax, VT, Environmental Tax, EI, GDP, FDI,	ARDL	ET is positively related with GDP and FDI
Li et al. (2021)	China	2017-2019	Heat, Tax rate, Air pollution,	---	Tax is negatively related with Air Pollution

			Environmental Pollution		

2.2.1. An Overview of the Literature Review

The issues of gross domestic product, gross capital formation, and environmental taxation have all been the subject of much literature investigation. However, more needs to be learned about the effects of air pollution. In previous literatures, environmental pollution employed as a proxy for the effects of air pollution (check, Mujtaba & Shahzad, 2021).This paper has considered GFCF, GDP, ET and APE variables for the research, previous prominent literature around the theme of ET and GDP nexus found significant negative relationships with GDP, the other hand GFCF considered as constructing agent for the GDP, air pollution and environmental pollution significantly found to be the positive factor in the reduction of environmental degradation with the substantial environmental taxes. In light of the literature which social scientists have found to be extremely essential, this paper of the thesis considers GFCG, ET, and APE as key players in the economies to prevent environmental degradation.

3. Data and the Model

In this thesis section, the type of the data of our variables and their sources is described. The panel data of the "gross fixed capital formation, gross domestic product, environmental taxes, and air pollution effects" is constructed by taking the timeseries data of 16 European countries (Henceforth: EU-16) which are as; "Austria, Belgium, France, Finland, Germany, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Spain, Sweden, and UK".

3.1. Data Source

The annual panel data, which were collected from 1994 to 2020, were utilized to analyze the data in this study. Type of data collection is annual basis. The data is mainly obtained from primary source i.e., (OECD, 2022) to avoid disability of the model and to draw the appropriate results. The main source of all the data type is OECD website of open database. The data of "Gross fixed capital formulation Growth and the Gross Domestic Product at constant price (Real GDP in $) and Air Pollution Effects" is taken in natural Logarithm to avoid the variability and maintain the smoothness of the data. The data of the Environmental Tax is taken in percentage terms as the percentage of GDP.

Table 2. Data Source & Description

Variables	Description	Unit	Form	Source
LnGFCF	Gross fixed capital formulation Growth	Level	Natural Logarithm	OECD
LnGDP	Real gross domestic product growth rate	Level	Natural Logarithm	OECD
Etax	Environmental Tax Rate	% Of GDP	-	OECD
LnAPE	Air Pollution Effects	Level	Natural Logarithm	OECD

*Source: OECD open data base.

3.2. Correlation Matrix

Correlation Matrix shows the coefficient of correlation between the variables of our model. The coefficient of correlation ranges between +1 and -1. From the table below, we can see that LnGFCF shows high positive correlation with LnGDP, meaning that "gross fixed capital formation and gross domestic product are highly correlated". Also, LnGFCF shows negative correlation with environmental tax (Etax) and positive correlation with air pollution effects (LnAPE).

Table 3. Correlation Matrix

Variables	LnGFCF	LnGDP	Etax	LnAPE
LnGFCF	1.00	0.99	-0.20	0.50
LnGDP	0.99	1.00	-0.17	0.52
Etax	-0.20	-0.17	1.00	0.27
LnAPE	0.50	0.52	0.27	1.00

3.3. Descritive Statisitcs

The table below shows the description of several statistics of our variables of European Countries taken into study at a glance.

Table 4. Descritive Statisitcs of the Variables

Descriptive Statistics	LnGFCF	LnGDP	Etax	LnAPE
Obs.	432	432	432	432
Max.	14.12	15.49	3.74	6.89
Min.	7.01	8.74	0.98	3.80
Mean	11.60	13.13	2.42	5.50
Std. Dev.	1.49	1.49	0.59	0.73
Skewness	-0.76	-0.72	0.07	-0.43
Kurtosis	3.63	3.43	2.56	2.38
Jarque - Bera	48.91	41.32	3.82	20.45
J-B Prob.	0.00	0.00	0.09	0.00

The data of all the variables of these European Countries has 432 number of observations. The "gross fixed capital formation, gross domestic product, environmental taxes, and air pollution effects" data is centered over 11.60, 13.13, 2.42, and 5.50 percent respectively.

The statistic standard deviation which measures the spread or the dispersion of the dataset of "gross fixed capital formation, gross domestic product, environmental taxes, and air pollution effects", in relation to its mean is 1.49, 1.49, 0.59, and 0.73 respectively.

The skewness is a statistic which measures the presence of asymmetry in the distribution of the dataset around its mean. For a normally distributed series, the value of skewness is zero. Therefore, the positive/negative value of skewness suggests "that there is long tail in the right/left side of the distribution". Environmental taxes have a tail on the right side of the distribution, whereas gross fixed capital formation, gross domestic product, and air pollution effects exhibit long tails on the left.

The kurtosis is a statistic which measures the presence of peaked-ness or the flatness of the distribution of the series. For a normally distributed series the value of Kurtosis statistic is 3. Therefore, the estimated Kurtosis values of all the variables shown above indicates the presence of peaks.

After estimating that the distribution has skewness as well as peak, it is indicated that the series distribution is normal. The Jarque-Bera probability confirms the presence of normal distribution in all the dataset from 1994 to 2020.

Following (Karmekar et al., 2021), we can write our empirical model in the following manner.

$$LnGFCF = a_0 + \alpha_{1i}\,LnGDP_{it} + a_{2i}Etax_{it} + a_{3i}LnAPE_{it} + \varepsilon_{i,t} \qquad (2)$$

Based on the empirical equation above our hypothesis of this paper are as follows:

Hypothesis 1: Gross Fixed Capital Formation and Gross Domestic Product are positively related i.e., $\alpha_{1i} > 0$.

Hypothesis 2: Gross Fixed Capital Formation and Environmental Tax are negatively related i.e., $\alpha_{2i} < 0$.

Hypothesis 3: Gross Fixed Capital Formation and Air Pollution Effects are positively related i.e., $\alpha_{3i} > 0$.

3.4. Justification of Hypothesis and Variables

These hypotheses are based on the theoretical framework, previous literature reviews, and several environmental economic theories. For example, first hypothesis is simply based on the macroeconomic principle that, “improvement in rate of economic growth can cause a substantial rise in investment or gross fixed capital formation” (Pettinger, 2019 economicshelp.org). Also, the second hypothesis follows the EKC hypothesis in a sense that, as per the literature review, economic growth and carbon emissions are positively related, meaning major economic activities are causing carbon emissions. Therefore, to curb the carbon emissions, if the environmental tax policies are levied on those economic activities, then it will reduce the future investment spendings. Hence, principally the environmental tax and gross fixed capital formation must be negatively related. Moreover, the third hypothesis again follows the positive (EKC) type relationship of economic growth and carbon emissions. Since, carbon emissions are causing serious socio-economic problems, for example, health, mortality rate, and life expectancy. Therefore, there must be "a positive linkage between gross fixed capital formation and air pollution effects, since investment spendings are done at the cost of environment, human-life, and humanity".

4. Methodology

A second-generation panel data approach was used in this thesis for EU-16 countries. We have adopted the advanced panel data techniques in these studies described in subsections. Cross-section dependence test, second generation panel unit root test, second generations panel cointegration test, and lastly the novel dynamic common correlated effects to estimate the coefficients followed by homogeneity test make up the remaining steps of the thesis.

4.1. Cross-sectional Dependence Test

This study has conducted many series of tests to analyze the presence of cross-sectional dependence in the panel like CD test, Lagrange multiple test, the scaled-LM test, the adjusted scaled-LM test, and Bias-corrected scaled LM test.

Bias-corrected scaled LM test can be described are as follows:

$$Bias - corrected\ Scaled\ LM = \sqrt{\left(\frac{1}{N(N-1)}\right)} \sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T_{ij}\widehat{P_{ij}^{2}} - 1) - \frac{N}{2(T-1)} \quad (3)$$

So, in case if the cross-section dependency is found in the series, the second-generation panel unit root test must be used.

4.2. CIPS Panel Unit Root Test

The second-generation panel unit root test knows as CIPS. Also, the mean of the CADF test estimates refers to the CIPS test which is as follows:

$$\text{CADF} = t(N,T) = \frac{\Delta y_i^{t}\,\bar{M}_i y_{i-1}}{(\Delta y_{i\text{-}1}^{t}\,\bar{M}_i y_{i-1})^{1/2}} \quad (4)$$

which is transformed into CIPS by averaging it as described below.

$$CIPS = N^{-1}\sum_{i=1}^{n} t(N,T) \quad (5)$$

4.3. Panel Cointegration Test

Westerlund (2007) panel cointegration tests to examine the existence of cointegration among the variables CO2, GDP, and GFCF. The null hypothesis is that there no cointegration among the variables. This test is more accurate as it takes into consideration all the issues such as heteroskedasticity, CDS, and serial correlation. Following cointegration equation represents the Westerlund (2007) are as follows:

$$\Delta LnGFCF_{2,i,t} = \alpha_i^C + \lambda_i^C\left(LnGFCF_{2,it-1} - \beta_i^C LnGDP_{2,it-1} - \gamma_i^C Etax_{i,t-1} - \lambda_i^C LnAPE_{i,t-1}\right) + \sum_{j=1}^{m}\theta_{i,j}^{G}\,\Delta LnGFCF_{2,it-j} + \sum_{j=1}^{n}\delta_{i,j}^{G}\,\Delta LnGDP_{it-j} + \sum_{j=1}^{p}\emptyset_{i,j}^{G}\,\Delta Etax_{i,t-j} + \sum_{j=1}^{o}\lambda_{i,j}^{G}\,\Delta LnAPE_{i,t-j} + \mu_{i,t} \quad (6)$$

4.4. Dynamic Common Correlated Effects (DCCE) Estimation Test

The Dynamic Common Correlated Effects methodology, which was recently created by (Chudik and Pesaran, 2015), was used in this study for the heterogeneous panel estimating outcomes for both short- and long-term estimations (Ditzen, 2018).

The following mentioned equation of DCCE can be written on behalf of the model specifications:

$$LnGFCF_{2,it} = a_i LnGFCF_{2,it-1} + \delta_i X_{it} + \sum_{p=0}^{pT}\gamma_{xip}\,\overline{X_{t-p}} + \sum_{p=0}^{pT}\gamma_{yip}\,\overline{Y_{t-p}} + \mu_{it} \quad (7)$$

The above equation, $a_i LnGFCF_{2,it-1}$is the log of gross fixed capital formation used as the dependent variables, $\delta_i X_{it}$ indicates the set of independent variables like LnGDP, Etax, and LnAPE are reported by the X_{it}.

5. Empirical Estimates

The test statistics and statistical estimates for our empirical model are provided in the following sequence in this section. The Cross-Section Dependence testing estimates are presented first. Second, we use the CIPS, and CADF unit roots tests to examine stationarity based on the results of the CD test. Thirdly, using the Westerlund test, we check for the existence of long run cointegration after validating the difference stationarity of all the variables. Following the discovery of long-run cointegration, we use the Dynamic Common Correlated Effects technique to estimate the long-run coefficients. We do the homogeneity test before calculating the coefficient to determine whether each unique coefficient is homogeneous or heterogeneous.

5.1. Cross Section Dependence Test

The cross-section dependence test is provided by several statistical approaches, including the Pesaran-CD, Pesaran-Scaled LM, and Bias Corrected Scaled LM. All test data in the table below display significant values. The p-values demonstrate that the variables are cross-sectionally dependent. Therefore, we use second-generation panel data analysis to estimate our model to solve the cross-section dependence issue.

Table 5. Cross Section Dependence Test

Variable	Pesaran-CD		Pesaran-scaled LM		Bias-corrected scaled LM	
	Stat.	**p-value**	**Stat.**	**p-value**	**Stat.**	**p-value**
LnGFCF	51.79	0.00*	166.62	0.00*	166.31	0.00*

LnGDP	56.19	0.00*	196.11	0.00*	195.80	0.00*
Etax	13.50	0.00*	50.06	0.00*	49.75	0.00*
LnAPE	42.45	0.00*	177.28	0.00*	176.97	0.00*
					Breusch-Pagan LM	
Model	10.06	0.00*	28.52	0.00*	561.95	0.00*

5.2. Panel Unit Root Tests

Depending on the CD tests, different strategies can be used to determine whether there are unit roots in a panel of data for a certain variable. We apply the IPS unit root test if the data do not exhibit any cross-sectional dependence; otherwise, we employ the CIPS and CADF test statistics. All the variables are differenced stationary, as can be seen in the table below. The statistically significant values are provided by the IPS, CIPS, and CADF test statistics. At the 1% level of significance, the LnGFCF, LnGDP, Etax, and LnAPE are differenced stationary, indicating that the long run cointegration of the variables can now be examined.

Table 6. IPS, CIPS, and CADF Unit Root Tests

Variables	**CIPS**		**CADF**	
	I(0)	**I(1)**	**I(0)**	**I(1)**
LnGFCF	-1.92	-3.82	-1.92	-3.82*
LnGDP	-1.67	-4.07*	-1.67	-4.07*
Etax	-1.77	-4.88*	-1.90	-3.05*
LnAPE	-0.94	-2.51*	-1.92	-2.36*

5.3. Westerlund (2007) Cointegration Test

The Westerlund (2007) test is preferable when cross-section reliance exists in the data set because it solves the cross-section dependence issue. All the p-values indicate that there is a long-term co-integration at a 1 percent level of significance, between all the variables.

Table 7. Westerlund (2007) Cointegration Test

Statistics	**Value**	**z-value**	**p-value**
Gt	-2.29	-2.29	0.01
Ga	-7.36	0.28	0.61
Pt	-9.79	-3.45	0.00
Pa	-7.78	-2.22	0.01

5.4. Slope Heterogeneity Test

Developed by (Pesaran & Yagamata, 2008), this test checks the homogeneity of the individual slope coefficients of the model. The null hypothesis of this test is that the slope coefficients are homogenous.

Table 8. Slope Heterogeneity Test

H0: Slope coef. homogenous	Delta	p-value
	18.94	0.00
Adj.	20.98	0.00

The p-values indicates that the null hypothesis of homogenous slope coefficients is rejected at 1 percent significance level.

5.5. Dynamic Common Correlated Effects

Dynamic Common Correlated Effects is a novel method, which is the key estimation technique of the second-generation panel data analysis. The DCCE method, overcomes, the cross-section dependence problem of the data modeled, structural breaks in the data arising from market and non-market fluctuations, and the problem of heterogeneity in the individual coefficients. Since, our data has cross-section dependence problem, and the individual coefficients are found to be heterogenous. This is the most appropriate method to estimate the long-run coefficients of our empirical model. The table below shows coefficients statistics in two different categories. The Pooled Mean Group and the Mean Group coefficient statistics. Both these categories show slightly different estimates.

Gross fixed capital formation and economic growth have a statistically significant positive association, according to the DCCE: PMG figures. The coefficient of LnGDP is 0.91 which is statistically significant at 1 percent level indicates that, with 1 percent increase in GDP in EU-16 countries, the gross fixed capital formation increases by 0.91 percent. Moreover, the DCCE: MG statistics also shows that there is a positive linkage between LnGDP and LnGFCF of EU-16 countries. However, the coefficient of LnGDP is 0.66 which is statistically significant at 5 percent level indicated that with 1 percent rise in LnGDP the LnGFCF rises by 0.66 percent. In conclusion we say both these coefficients are statistically significant and are consistent with the (Pettinger, 2019) and accepts our first hypothesis.

Table 9. DCCE- Pooled Mean Group & Mean Group Estimates

	Pooled Mean Group		**Mean Group**	
D.LnGFCF	Coef.	p-value	Coef.	p-value
L.LnGFCF	-0.72	0.00*	-0.49	0.00*
LnGDP	0.91	0.00*	0.66	0.03**
LnAPE	0.30	0.07***	0.15	0.04**
Etax	-0.03	0.09***	-0.07	0.05**
Const.	-0.95	0.71	2.49	1.00

Also, the DCCE: PMG estimates found LnGFCF to be positively related with the air pollution effects. The coefficient of LnAPE is 0.30 which is statistically significant at 10 percent level indicates that with 1 percent rise in air pollution effects, the gross fixed capital formation rises by 0.30 percent. However, the DCCE:MG statistics also show that LnAPE and LnGFCF to be positively related. The coefficient of LnAPE is 0.15, which is statistically significant at the 5% level showed that the GFCF increases by 0.15 percent for every 1 percent increase in LnAPE. Thus, in conclusion, these estimated coefficient of LnAPE is consistent with the (Nchege & Okpalaoka, 2022) and (Mujtaba & Shahzad, 2021) and confirms our second hypothesis.

Moreover, the DCCE: PMG estimates found that environmental tax and gross fixed capital formation are negatively related. The coefficient of Etax is -0.03, which is statistically significant at 10 percent level indicates that with 1 percent rise in Etax, the LnGFCF falls by 0.03 percent. However, the DCCE:MG statistics also show that Etax and LnGFCF to be negatively related. The coefficient of Etax is -0.07, this is statistically significant at the 5% level and showed that the GFCF decreases by 0.07 percent for every 1 percent increase in Etax. Thus, in conclusion the established relationship and estimated coefficient is consistent with (Hassan et al, 2012), (Abdullah & Morley, 2014), and (Miceikiene et. al, 2018).

6. Conclusion

This paper of this thesis tries to establish the long run relationship between gross fixed capital formation as a dependent variable with independent variables such as, gross domestic product, air pollution effects, and environmental tax in EU-16 countries between 1994-2021 time-period by adopting second generation panel data analysis techniques. The research questions or the hypothesis were, first, Gross Fixed Capital Formation and Gross Domestic Product are positively related, second, Gross Fixed Capital Formation and Air Pollution Effects are positively related, and third, Gross Fixed Capital Formation and Environmental Tax are negatively related. The Novel DCCE estimation technique was adopted to estimate the long-run coefficients. The empirical estimation part showed that all variables and the econometric model has cross-section dependence. Also, the second-generation unit roots test also confirmed differenced stationarity at 1 percent statistical significance. In addition, using panel cointegration tests, it was confirmed that all the variables are cointegrated in the long run. Moreover, slope homogeneity test confirmed that individuals slope coefficients are heterogenous. Finally, the adoption of novel DCCE method gave reliable estimates of the long-run coefficients. The DCCE estimates confirmed all the hypothesis. Firstly, long run cointegration and positive relationship between Gross Fixed Capital Formation and Gross Domestic Product was found. Second, it was discovered that Gross Fixed Capital Formation and the effects of air pollution have a positive association and long-term cointegration. Thirdly, long run cointegration and negative relationship between Gross Fixed Capital Formation and Environmental Tax was also obtained. Therefore, based on the estimated results we can conclude that, EU-16 countries are experiencing the high economic growth, due to investment spendings at the cost of environmental degradation since the air pollution effects are found to be positively related with gross fixed capital formation. However, at the same time, the negative relationship established between environmental tax and gross fixed capital formation shows that adoption of environmentally friendly policies such as environmental tax keeps the non-sustainable economic growth at check, and this is consistent with the policy recommendations of previous researchers mentioned in the literature review. Hence, we can say that the theoretical framework, the econometric model, and the empirical estimates provided the most consistent, novel, and reliable results.

References

[1] Abdullah, S., & Morley, B. (2014). Environmental taxes and economic growth: Evidence from panel causality tests. *Energy Economics*, *42*, 27-33.

[2] Ahmad, M., Chandio, A. A., Solangi, Y. A., Shah, S. A. A., Shahzad, F., Rehman, A., & Jabeen, G. (2021). Dynamic interactive links among sustainable energy investment, air pollution, and sustainable development in regional China. *Environmental Science and Pollution Research*, *28*(2), 1502-1518.

[3] Aloi, M., & Tournemaine, F. (2011). Growth effects of environmental policy when pollution affects health. *Economic Modelling*, *28*(4), 1683-1695.

[4] Andreoni, V. (2019). Environmental taxes: Drivers behind the revenue collected. *Journal of cleaner production*, *221*, 17-26.

[5] Bashir MF, Ma B, Shahbaz M, Jiao Z. The nexus between environmental tax and carbon emissions with the roles of environmental technology and financial development. PloS One 2020;15:1e20. https://doi.org/10.1371/journal.pone.0242412.

[6] Bashir, M. F., Ma, B., Shahbaz, M., & Jiao, Z. (2020). The nexus between environmental tax and carbon emissions with the roles of environmental technology and financial development. *PLoS One*, *15*(11), e0242412.

[7] Bosquet, B. (2000). Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological economics*, *34*(1), 19-32.

[8] Chen W, Zhou JF, Li SY, Li YC. Effects of an energy tax (carbon tax) on energy saving and emission reduction in guangdong province-based on a CGE model. Sustain Times 2017;9. https://doi.org/10.3390/su9050681.

[9] Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of econometrics*, *188*(2), 393-420.

[10] COM, E. (2011). A Roadmap for moving to a competitive low carbon economy in 2050. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*, *112*.

[11] Degirmenci, T., & Aydin, M. (2021). The effects of environmental taxes on environmental pollution and unemployment: A panel co-integration analysis on the validity of double dividend hypothesis for selected African countries. *International Journal of Finance & Economics*.

[12] Ditzen, J. (2016). xtdcce: Estimating dynamic common correlated effects in Stata. *The Spatial Economics and Econometrics Centre (SEEC)*, *1601*.

[13] Ditzen, J. (2018). Estimating dynamic common-correlated effects in Stata. *The Stata Journal*, *18*(3), 585-617.

[14] Dogan, E., Seker, F., & Bulbul, S. (2017). Investigating the impacts of energy consumption, real GDP, tourism and trade on CO2 emissions by accounting for cross-sectional dependence: a panel study of OECD countries. Current Issues in Tourism, 20(16), 1701-1719.

[15] European Commission. (2014). A policy framework for climate and energy in the period from 2020 to 2030. *Technical Report COM (2014)*, 15.

[16] Fern_andez Fern_andez Y, Fern_andez L_opez MA, Olmedillas Blanco B. Innovation for sustainability: the impact of R&D spending on CO2 emissions. J Clean Prod 2018;172:3459e67. https://doi.org/10.1016/j.jclepro.2017.11.001.

[17] Freire-González, J. (2018). Environmental taxation and the double dividend hypothesis in CGE modelling literature: A critical review. *Journal of Policy Modeling*, *40*(1), 194-223.

[18] Ghaith AF, Epplin FM. Consequences of a carbon tax on household electricity use and cost, carbon emissions, and economics of household solar and wind. Energy Econ 2017;67:159e68. https://doi.org/10.1016/j.eneco.2017.08.012

[19] Ghazouani, A., Jebli, M. B., & Shahzad, U. (2021). Impacts of environmental taxes and technologies on greenhouse gas emissions: contextual evidence from leading emitter European countries. *Environmental Science and Pollution Research*, *28*(18), 22758-22767.

[20] Goulder, L. H., & Parry, I. W. (2020). Instrument choice in environmental policy. *Review of environmental economics and policy*. page-152-174.

[21] Hammar H, Sj€ostr€om M. Accounting for behavioral effects of increases in the carbon dioxide (CO2) tax in revenue estimation in Sweden. Energy Pol 2011;39:6672e6. https://doi.org/10.1016/j.enpol.2011.06.014.

[22] Hashmi, R., & Alam, K. (2019). Dynamic relationship among environmental regulation, innovation, CO2 emissions, population, and economic growth in OECD countries: A panel investigation. *Journal of cleaner production*, *231*, 1100-1109.

[23] Hassan, M., Oueslati, W., & Rousselière, D. (2020). Environmental taxes, reforms and economic growth: An empirical analysis of panel data. *Economic Systems*, *44*(3), 100806.

[24] He, P., Sun, Y., Niu, H., Long, C., & Li, S. (2021). The long and short-term effects of environmental tax on energy efficiency: Perspective of OECD energy tax and vehicle traffic tax. *Economic Modelling*, *97*, 307-325.

[25] Holland, S. P. (2009). *Taxes and trading versus intensity standards: second-best environmental policies with incomplete regulation (leakage) or market power* (No. w15262). National Bureau of Economic Research. Jiang Z, Shao S. Distributional effects of a carbon tax on Chinese households: a case of Shanghai. Energy Pol 2014;73:269e77. https://doi.org/10.1016/j.enpol.2014.06.005.

[26] Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. Journal of econometrics, 115(1), 53-74.

[27] Ipek, E. (2022). Agricultural Sector in the Fight Against Climate Change: Smart Agricultural Practices for Sustainable Agricultural Economy. Adam Academy Journal of Social Sciences, 12 (1), 225-242 . DOI: 10.31679/adamakademi.878962.

[28] Kahouli B. The causality link between energy electricity consumption, CO2 emissions, R&D stocks, and economic growth in Mediterranean countries (MCs). Energy 2018;145:388e99. https://doi.org/10.1016/j.energy.2017.12.136.

[29] Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, *90*(1), 1-44.

[30] Karmaker, S. C., Hosan, S., Chapman, A. J., & Saha, B. B. (2021). The role of environmental taxes on technological innovation. *Energy*, *232*, 121052.

[31] Khan, I., Hou, F., Zakari, A., Tawiah, V., & Ali, S. A. (2021). Energy use and urbanization as determinants of China's environmental quality: prospects of the Paris climate agreement. *Journal of Environmental Planning and Management*, 1-24.

[32] Li, P., Lin, Z., Du, H., Feng, T., & Zuo, J. (2021). Do environmental taxes reduce air pollution? Evidence from fossil-fuel power plants in China. *Journal of Environmental Management*, *295*, 113112.

[33] Li, Z., & Sun, J. (2015). Emission taxes and standards in a general equilibrium with entry and exit. *Journal of Economic Dynamics and Control*, *61*, page 34-60.

[34] Lin B, Li X. The effect of carbon tax on per capita CO2 emissions. Energy Pol 2011; 39:5137e46. https://doi.org/10.1016/j.enpol.2011.05.050.

[35] Mauderly, J. L., & Samet, J. M. (2009). Is there evidence for synergy among air pollutants in causing health effects?. *Environmental health perspectives*, *117*(1), 1-6.

[36] Meng S, Siriwardana M, McNeill J. The environmental and economic impact of the carbon tax in Australia. Environ Resour Econ 2013; 54:313e32. https://doi.org/10.1007/s10640-012-9600-4.

[37] Miceikiene A, Ciuleviciene V, Rauluskeviciene J, Streimikiene D. Assessment of the effect of environmental taxes on environmental protection. Ekon Cas 2018; 66:286e308.

[38] Mujtaba, G., & Shahzad, S. J. H. (2021). Air pollutants, economic growth and public health: implications for sustainable development in OECD countries. *Environmental Science and Pollution Research*, *28*(10), 12686-12698.

[39] Mujtaba, G., & Shahzad, S. J. H. (2021). Air pollutants, economic growth and public health: implications for sustainable development in OECD countries. *Environmental Science and Pollution Research*, *28*, 12686-12698.

[40] Nchege, J., & Okpalaoka, C. (2022, March). Air pollution and economic growth nexus in Nigeria: the case for environmental sustainability. In *IOP Conference Series: Earth and Environmental Science* (Vol. 993, No. 1, p. 012007). IOP Publishing.

[41] Nchege, J., & Okpalaoka, C. (2022, March). Air pollution and economic growth nexus in Nigeria: the case for environmental sustainability. In *IOP Conference Series: Earth and Environmental Science* (Vol. 993, No. 1, p. 012007). IOP Publishing.

[42] OECD (2022), Air pollution effects (indicator). doi: 10.1787/573e3faf-en (Accessed on 15 September 2022)

[43] Ortiz, A., Guerreiro, C., & Soares, J. (2020). Air Quality in Europe—2020 Report. *European Environment Agency (EEA) and European Topic Centre on Air Pollution, Noise, Transport and Industrial Pollution (ETC/ATNI)*, *9*, 1-162.

[44] Pautrel, X. (2009). Pollution and life expectancy: How environmental policy can promote growth. *Ecological Economics*, *68*(4), 1040-1051.

[45] Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and statistics*, *61*(S1), 653-670.

[46] Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory*, *20*(3), 597-625.

[47] Pereira Sánchez, Á., & Vence Deza, X. (2015). Environmental policy instruments and eco-innovation: an overview of recent studies. *Innovar*, page *25*(58), 65-80.

[48] Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of econometrics*, *68*(1), 79-113.

[49] Pesaran, M. H., & Smith, R. (2006). Macroeconometric modelling with a global perspective. *The Manchester School*, *74*, 24-49.

[50] Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics*, *142*(1), 50-93.

[51] Pettinger, T. (2019). Environmental kuznets curve. Economics Help.

[52] Pigou, A. C., & Aslanbeigui, N. (2017). *The economics of welfare*. Routledge. Popp, D., Newell, R. G., & Jaffe, A. B. (2010). Energy, the environment, and technological change. *Handbook of the Economics of Innovation*, *2*, page 873-937.

[53] Safi, A., Chen, Y., Wahab, S., Zheng, L., & Rjoub, H. (2021). Do environmental taxes achieve the carbon neutrality target of G7 economies? Evaluating the importance of environmental R&D. *Journal of Environmental Management*, *293*, 112908.

[54] Shahzad, U. (2020). Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications. *Environmental Science and Pollution Research*, *27*(20), 24848-24862.

[55] Shaikh, O. (2020). Divisive politics and economic development. Journal of Politics, Economy, and Management 3(2), 22-30.

[56] SHAİKH, H., & SHAİKH, O. COVID-19 AND CHALLENGES TO ECONOMIC MODELS AND POLITICAL REGIMES. Academic Review of Humanities and Social Sciences, 4(1), 98-115.

[57] Sun Y, Lu Y, Wang T, Ma H, He G. Pattern of patent-based environmental technology innovation in China. Technol Forecast Soc Change 2008;75: 1032e42. https://doi.org/10.1016/j.techfore.2007.09.004.

[58] Sundar S, Mishra AK, Naresh R. Effect of environmental tax on carbon dioxide emission: a mathematical model. Am J Appl Math Stat 2016;4:16e23. https://doi.org/10.12691/ajams-4-1-3.

[59] Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and statistics*, *69*(6), 709-748.

[60] Yang L, Li Z. Technology advance and the carbon dioxide emission in China empirical research based on the rebound effect. Energy Pol 2017;101: 150e61. https://doi.org/10.1016/j.enpol.2016.11.020.