Universitetet i Stavanger

Handelshøgskolen ved UiS

Exploring the causal links between green investment, carbon emissions, renewable energy consumption, and economic growth.

Master Thesis within Business Administration

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Submission date: 15th July 2023

Universitetet
i Stavanger

UNIVERSITY OF STAVANGER BUSINESS SCHOOL

MASTER'S THESIS

STUDY PROGRAM:	THESIS IS WRITTEN IN THE FOLLOWING SPECIALIZATION:
Master of Science in Business Administration	Economics IS THE ASSIGNMENT CONFIDENTIAL? (**NB**! Use the red form for confidential theses)

TITLE:

"Exploring the causal links between green investment, carbon emissions, renewable energy consumption, and economic growth".

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The global economy is affected by ecological imbalance and climate challenges. Non-renewable energy consumption and carbon emissions are crucial reasons behind environmental degradation. Global awareness regarding climate change and environmental degradation is currently at its highest point. This thesis aims to explore and recognize the causal links between green investment, carbon emissions, renewable energy consumption, and economic growth of ten European Union countries from 2010 to 2019.

Through a comprehensive literature review on the same line of scholarly research, we gained valuable and in-depth insight into the previously explored relationships between the concepts of our study. Further, in a theoretical framework, we have evaluated and discussed the relevant theories, such as the Environmental Kuznets curve, Harrod Domar growth model, and the Environmental growth hypothesis, which are applied to determine the causal links that exist between the selected variables of our thesis. For the empirical analysis, we have extracted secondary data from the World Bank's World Development Indicator's online database and Eurostat. The empirical results and discussion part started with descriptive statistics, correlation analysis, and unit root tests to understand the essential characteristics of the variables. Further, we adopted the linear and quadratic regressions, the vector autoregressive model (VAR), and the Granger causality test to determine the statistical significance and direction of the causal relationship between the key variables of our thesis.

Our research findings show positive and negative correlations among all the variables, but all the coefficients are not statistically significant among all the models. The quadratic regression and VAR model show that renewable energy consumption has a negative relationship with carbon emissions and a positive impact on economic growth. Furthermore, green investment and carbon emissions showed a statistically significant relation with economic growth. The Granger causality test found that renewable energy has a bidirectional causality with carbon emissions and green investment. Economic growth also has a bidirectional causality with carbon emissions. However, the nexus between green investment and carbon emissions is unidirectional.

According to the analysis results, we recommend adopting policies that promote green investments and encourage renewable energy consumption to reduce carbon emissions, ultimately achieving sustainable economic growth.

PREFACE

This master's thesis is a requirement for the fulfilment of our Master of Science in Business Administration program, Economics specialization. It was conducted under the supervision of Dr, Sufyan Ullah Khan. We sincerely appreciate his time, effort, and guidance during development of this thesis. Even when he was out of the country, his constructive criticism and availability was most especially overwhelming.

Our study on exploring the causal links between green investment, carbon emission, renewable energy consumption and economic growth was conducted using data from the world bank and the Eurostat. They were forthcoming and helpful in our inquiries and correspondence with them. We utilized R studio for our econometric analysis and made use of Grammarly for sentence restructuring and language improvement.

Working on this thesis was both challenging and interesting, new knowledge was gained, limits were tested and in all we came out on top. We thank all our professors for the knowledge instilled without which this thesis would not have come to fruition. A special thanks goes to Prof. Gorm Kipperberg, who helped us immensely and shared incredible insights throughout our study.

Finally, we want to acknowledge our family and friends, thank you for your continuous support and patience.

LIST OF ABBREVIATIONS

European Union	EU
Green House Gases	GHG
Organisation for Economic Co-operation and Development	OECD
International Monetary Fund	IMF
International Energy Agency	IEA
World Development Indicators	WDI
International Renewable Energy Agency	IRENA
Carbon Emissions	CO_2
Renewable energy consumption	REC
Gross Domestic Product per capita	PGDP
Green Investment	GINV
Environmental Taxes	ETAX
Government Expenditure on Education	GEDU
Urban Population	UP
Environmental Kuznets Curve	EKC
Ordinary Least Squares	OLS
Dynamic Ordinary Least Square	DOLS
Vector Error Correction Model	VECM
Fully Modified Ordinary Least Square	FMOLS
Generalized Method of Moments	GMM
Purchasing Power Parity	PPP
Augmented Dickey Fuller test	ADF
Levin Lin Chu	LLC
Vector Autoregression	VAR
Autoregressive Distributed Lag	ARDL
Non-Linear Autoregressive Distributed Lag	NARDL
Nomenclature of Economic activities	NACE

CHAPTER 1: INTRODUCTION

1.1 Problem Statement

Global warming has been one of the most prevalent issues, especially in the last few decades. Esso & Keho (2016) considers Greenhouse gases (GHG) mainly carbon emissions, as the main threatening cause of global warming. Zahan & Chuanmin (2021) agree that environmental pollution is one of the main hurdles to sustainable development. Raihan et al. (2022) exert that the unchecked rise in carbon emissions is expected to have incredibly negative effects on the climate, with its consequences reportedly going to affect all segments of civilization. Priyan (2023) rightly argues that climate change is the greatest security threat contemporary humanity has faced in this current century. She continued that its leading cause is greenhouse gases, particularly carbon emissions. The list of scholars being vocal about the threat to the environment that we now face is never-ending. Perhaps it goes to show how important and relevant this phenomenon is.

As a matter of record, countries are becoming increasingly conscious about the environment, the degradation of it, and the subsequent rush to remedy the ailing situation. According to Zhang et al. (2022), the protection of the environment is no longer just a pressing societal issue; it has indeed become a shared problem and an obligation for all. This point is reiterated by Hung (2023) when he asserted that academics, industry representatives, and policymakers have increased attention to sustainable development. Therefore, the topic of carbon emissions, renewable energy, and green investment is the talk of all economies. When you add the overall goal of all economies, which is 'Economic Growth,' this becomes one of the most pressing issues in the modern days. As rightly pointed out by Sharif et al. (2023), the issue of environmental deterioration and climate change not only poses a threat to human health but also to income and productivity levels.

The issue of environmental degradation has taken center stage in most climate change conversations among world leaders (Yuping et al. 2021). This has caused the priorities of international organizations to be adjusted as they understand the urgency needed to tackle climate change and bring about sustainable growth and development. This renewed zeal has brought about programs like the Kyoto Protocol, the Paris Agreement, and the EU Fit for 55. The United Nation's Sustainable Development Goals for 2030 and their targets and indicators all point to the level of importance being placed on affordable, clean, and renewable energy sources and consumption in the world today. All this, however, might not be enough. OECD (2018) claim that carbon pricing is not enough to alleviate the global environmental issues. Therein lies the importance of green investment. To bring about the much-needed change, our actions must be proactive rather than just reactive.

Yuping et al. (2021) claim that because of the renewed awareness of the dangers of climate change, a host of scholars have been trying to explore and study the macroeconomic factors responsible for this deterioration of the global environment. Also collaborated by Raihan et al. (2022) is of the idea that the pursuit of ways to lower carbon emissions has become an objective for modern-day researchers who explore a host of ways in their bid to build a green and sustainable world.

1.2 Purpose and Objective of the Study

The world today is past the stage of ignorance regarding the state of its environment. We are struggling with the numerous challenges brought forth by climate change. Challenges like increased temperature, erosion, flooding, heat waves, and rising sea levels. This has shifted the focus to finding ways of decreasing carbon emissions, promoting green investments, and increasing renewable energy sources and their consumption together. All these while still seeking economic growth. This thesis strives to connect the dots around these issues of today's world. By exploring and understanding the relationships between these phenomena, this research will provide an understanding of the potential synergies that exist between these concepts. Any trade-off that can be reached on the road to achieving sustainable growth and development is also explored.

The objective of this study is to provide empirical evidence and an in-depth understanding of the kind of relationship that exists between green investment, carbon emissions, renewable energy consumption, and economic growth of the selected ten European Union countries. This is in a bid to gain valuable insights on the road to reaching economic development that will coincide with environmental viability and sustainable development goals.

To point out in more clear terms, the objectives of this study are as follows:

O1: To determine what influence green investment has on renewable energy consumption and economic growth.

O2: To analyse how economic growth is affected by carbon emissions and renewable energy consumption.

O3: To explore the relationship between green investment, renewable energy consumption, carbon emissions and economic growth.

1.3 Research Questions

Considering the research objective and in an effort to estimate them, we set up the research questions as follows:

RQ1: Does green investment have a significant influence on renewable energy consumption and economic growth?

RQ2: How do carbon emissions and renewable energy consumption affect economic growth?

RQ3: Is there a causal relationship between green investment, renewable consumption, carbon emissions and economic growth?

1.4 Choice of Methodology

This thesis is based on a quantitative research method using secondary data from two sources. This study employed an extensive empirical approach, and the research design is a descriptive model comparison. The models adopted are the Linear and Quadratic Regression, Vector Autoregression (VAR) model, and Granger causality tests. These models were adopted based on the research done by Chen et al. (2016) and Li &Zheng (2012). This kind of analysis is popularly carried out using the ARDL and VAR models. Yazdi & Shakouri (2017), who utilized both models, claimed that VAR's main difference from ARDL is that it assumes each variable as a linear function of its past value; meanwhile, ARDL is used for analyses of relationships over time and allows for non-linear relationships too. Bekun (2022) also claim that analyses like the Granger causality, Variance decomposition are more accessible and commonly used in the analysis of the VAR model.

A significant part of the data applied in the analysis is panel data that is based on World Bank's World Development Indicators. In addition, data is also collected from Eurostat for other variables that were not available at World Bank's WDI database. The dataset on government environmental spending and economic growth, pooled across ten European countries for ten years, will help to ensure the robustness of this study.

1.5 Significance of the Study

The idea behind identifying and understanding the causal links between green investment, carbon emissions, renewable energy consumption, and economic growth is that they can inform policy decisions and interventions aimed at reducing carbon emissions, promoting renewable energy consumption, and achieving sustainable economic growth. So, with the findings of this study, policymakers can be armed with the correct information to design, formulate, and implement policies that will advance green investment, aid transitioning to renewable energy, and bring about all round sustainable economic growth.

This study also has excellent consequences for global cooperation. An in-depth understanding of the causal links between our concepts will plot a path to strengthening international alliances and partnerships in achieving sustainable development goals, renewable energy sources development, and climate change alleviation. Another undeniable importance of this research is that it will provide a blueprint for understanding the economic viability and potential benefits to be derived from green investment. This, in turn, gives an outline to increased allocation of investments to green initiatives, higher technological innovations, and movement towards a low-carbon economy.

Figuring out the relationships between the variables under study will improve understanding of target areas in the economy that will bring about environmental efficiency that is showing the most efficient way to reduce carbon emissions while also encouraging economic growth. Clearly put, it will help provide a roadmap to sustainable growth and development, aid in the design of effective climate mitigation strategies, and ensure environmental viability. This research will ultimately be of significance to other scholars as we hope that, in the end, we will have contributed to the understanding of these complex but important relationships between green investment, carbon emissions, renewable energy consumption, and economic growth. It will also serve as academic literature and a basis for researchers who would want to continue this line of study.

1.6 Thesis Structure

The rest of the thesis is structured and divided into five chapters. Firstly, the background and literature section (chapter 2) describes in brief detail the four main variables under study, then an overview of the literature on these variables and how they have been known to interact with each other as reviewed by other scholars. This is followed by the theoretical framework chapter, which exposes some of our variables' theoretical backings regarding interactions between them. This is immediately followed by the data and methodology, where we present our different models and set a tone for model comparison. In the fifth chapter, we present and discuss our results, comparing the theory and our empirical findings. Finally, the thesis ends with a conclusion in chapter six, which includes a summary of our main findings, highlighting our contributions, giving some policy recommendations, and suggesting avenues for further research.

CHAPTER 2: BACKGROUND AND LITERATURE

2.1 Background

As all economies strive for economic development, it should not be to the detriment of the future generation. Correctly stated, economic advancement and environmental sustainability should go hand in hand (Azam, 2019). Tugcu & Menegaki (2023) asserts that sustainable, affordable, reliable, clean energy for all is one of the most pressing and essential goals of twenty-first-century economies. Transition to low-carbon production methods and energy sources is no longer enough. Environmentally safe sources of energy that are inexhaustible are the way to go today. Raihan et al. (2022) argued that advancement in technology seems like the most significant way to alleviate climate change. To finance and fund this advancement calls into action a conscious investment into green technologies. According to Musah et al. (2022), investments in green projects are three-pronged, they are; vital for economic growth, environmental protection, and resource conservation.

Eurostat (2017) defined carbon emissions as emissions from the burning of fossil fuels and the manufacture of cement. it includes carbon dioxide produced during the consumption of solid, liquid, and gas fuels as well as gas flaring. Zhang-Wei & Xun-gang (2012) posited that global carbon emissions have increased by more than 100% since the early 1970s and much of this increase is believed to be linked to the substantial growth in the world economic output. Bakry et al. (2023) claim that the share of carbon emissions is 75% of the global greenhouse gases.

Like most coined words, there has been a variety of definitions of what green investment means. Literature has shown that it is often used interchangeably used with green finance and green bond. A paper by Eyraud et al. (2011) for the International Monetary Fund (IMF) defined green investment as the investment needed to decrease greenhouse gas and air pollutant emissions without reducing the production and consumption of non-energy goods. They went further to define three classes of green investment as Low-emission energy supply (including renewable energy, biofuels, and nuclear); energy efficiency (in energy supply and energy-consuming sectors); and carbon capture and sequestration (including deforestation and agriculture).

A recent report for the OECD by Della Croce et al. (2011) posited that green investment refers to low carbon and climate-resilient investment made in companies, projects, and financial instruments that operate primarily in the renewable energy, clean technology, environmental or sustainability-related markets as well as those investments that are climate change specific. Luo et al. (2021) explained that green investment is any expenditure that helps to improve the efficacy of the manufacturing procedure. They include investments that include energy conservation, renewable resources, incorporate recycling, waste management, industrial pollution reduction, water cleanliness, biodiversity preservation, and climate change adaptation and mitigation.

Bakry et al. (2023) posited that a host of researchers have put forward different measures to help reduce the effects of carbon emissions, including innovation, carbon trading, and green finance. The scholars, however, argue that the role of green finance is critical in reducing carbon emissions. They claim that since its emergence, its priority in advancing green financial innovation and development has been of enormous use in tackling and impeding environmental degradation. Sharif et al. (2023) were also of the opinion that investment in green technology could be a cure to the environmental degradation issues of the world. Musah et al. (2022) spoke strongly about green investment when they said that investments in green projects are vital for economic growth, environmental protection, and resource conservation.

The need for the development of renewable energy is said to be a result of the enormous contribution of the energy sector to the global carbon emissions. Hence, to reduce the carbon footprint, renewable energy consumption is important. Perfectly explained by Ahmed et al. (2022) *'The greening of the world energy sector is deemed pertinent for curbing emissions and achieving environmentally sustainable economic growth across the globe since the energy sector on the average generates about three-fourths of the global carbon emissions.*' In the words of Azametal (2021), *'The rapid depletion of fossil fuels and their severe environmental effects are forcing economies to seek renewable energy sources.'* They claim the relevance of renewable energy is brought by the growing and justified concern for environmental sustainability.

The International Energy Agency (IEA), on its website, defines renewable energy as energy obtained from natural sources that are refilled at a higher rate than they are consumed. This is further made complete by the International Renewable Energy Agency (IRENA) in their definition of renewable energy as all forms of energy produced from renewable sources in a sustainable manner, including bioenergy, geothermal energy, hydropower, ocean energy, solar energy, and wind energy.

Raisová & Ďurčová (2014) defined economic growth as the expansion in the volume of an economy to produce goods and services, compared from one period to another. Kuznets (1973) defined economic growth as a long-term rise in the magnitude of an economy to supply increasingly diverse economic goods to its population. There has been a lot of diversity in the macroeconomic factors that stimulate economic growth, such as government expenditure (Forte & Magazzino, 2016), military spending and public debt (Esteve & Tamarit, 2018). Campos et al. (2022) posited that financial development and trade openness were needed for economic growth. Dore & Teixeira (2023) argues in their study of Brazil that human capital accumulation and industrialization are responsible for economic growth.

Amid all these arguments about economic growth, Yuping et al. (2021) claim that the main concern of economists today is how economic growth can be advanced without adding to damage done to the environment. This is put differently by Zhang (2022) when he said that environmental performance alongside economic growth has become a global requirement. Sustainable economic development is now the watchword and has got everyone's attention (Singh et al., 2022).

2.2 Carbon emissions and Economic growth

Sreenu (2022), in his study, employed both ARDL, NARDL and the Environmental Kuznet Curve to determine the effect of economic growth on carbon emissions. The research showed that a rise in economic growth would reduce carbon emissions. In contrast, a decrease in economic growth will increase carbon emissions which indicates an inverted U-shaped Curved relationship between economic growth and carbon emissions. Alam et al. (2016), in their ARDL-assisted study, employed annual time series data from 1970 to 2012 for their selected countries. They claimed that economic growth has been known to bring about an increase in carbon emissions. He reiterated the presence of EKC in Brazil, China, and Indonesia, then concluded that carbon emissions will eventually fall in the long run as economic growth continues. Alam et al. (2016) found a positive relationship to exist between economic growth and carbon emissions in India.

Esso and Keho (2016) studied the long run and causality relationship that exists between carbon emissions, economic growth, and energy consumption in 12 sub–Saharan African countries on annual data from 1971 to 2010. Their study found evidence of bidirectional causality between economic growth and carbon emissions in 3 countries, then reverse causality from carbon emissions to economic growth in 3 countries. Overall, the research found that economic growth leads to increased carbon emissions. More recently, Alaganthiran & Anaba (2022) conducted another study on the sub-Saharan African region. This time, pooled OLS, fixed, and random effects models were used with data from 20 countries from 2000 to 2020. Empirical evidence from their study showed that there exists a significant relationship between economic growth, energy consumption, and carbon emissions in the countries. They established that a 1% increase in economic growth would lead to an increase of about 0.02% in the carbon emissions level.

2.3 Renewable energy consumption and Carbon emissions

Akadiri and Adebayo (2022) from their study proved that a positive shock in non-renewable energy consumption increases carbon emissions, whereas an increase in renewable energy consumption leads to a decrease in carbon emissions. Their research was carried out using yearly data from 1970 to 2018 and employed the ARDL model for their study. Chen et al. (2016) reiterated the view above. They adopted the panel cointegration and vector autoregression model to investigate the global relationship that exists between carbon emissions, energy consumption and economic growth. A time series for 188 countries from 1993 to 2010 was used, and the research yielded a negative connection between the use of renewable energy and carbon emissions.

Raihan et al. (2022) adopted the ARDL, DOLS and utilized time series data of Bangladesh from 1980 to 2019. They aimed to investigate the possibility of attaining environmental sustainability through economic growth, renewable energy consumption, and technological innovation. Their results showed that the coefficient of renewable energy use is negative and significant. Thus, an increase of 1% in renewable energy use reduces carbon emissions by 0.15%. Their study also showed a positive and significant relationship between economic growth and carbon emissions too. Usman et al. (2020) used the Toda-Yamamoto causality test and ARDL to obtain the direction of causality, and short and long-run dynamic coefficients, respectively. They found out that increased renewable energy consumption leads to a decline in environmental degradation and so recommended energy policies that increase the share of renewable energy in the energy portfolio. Their study also concluded that economic growth positively affected the ecological footprint, and this positive relationship was also found to be a two-sided causal relationship.

Bosah et al. (2023), in their study, did not focus solely on renewable energy and performed a continental comparison of the effect of energy consumption on carbon emissions. He also investigated the effect economic growth had on carbon emissions too. Their study was across a sample of 159 countries. According to empirical evidence from their study, Africa, Asia, Europe, and Australia all showed that energy consumption had a positive effect on carbon emissions. North and South America showed energy consumption as having an insignificant effect on carbon emissions. Their study also included the effects of economic growth on carbon emissions. Unlike energy consumption, there was no consensus on their results. Africa, Asia, and Europe showed that economic growth had a negative effect on carbon emissions, while Australia, North and South America results showed economic growth as having an insignificant effect on carbon emissions. In trying to summarise their analysis on a global level, energy consumption was found to have a positive effect on carbon emissions. The reverse, however, is the case of economic growth. Their global analysis showed economic growth has a negative effect on carbon emissions.

2.4 Renewable energy consumption and Economic growth

Tugcu & Menegaki (2023) studied the impact of renewable energy consumption on economic growth in the United States. They used causality analysis, cointegration, and augmented unit root for their analysis. Their results revealed that, in the long run, renewable energy consumption will Granger cause economic growth. They argued that their study supported the growth hypothesis in the commercial sector.

Alper and Oguz (2016) studied the role of renewable energy consumption in economic growth using the autoregressive distributed lag (ARDL) approach asymmetric causality test approach. This study was performed on new EU countries from 1990 to 2009 and found that renewable energy consumption has a positive impact on economic growth for all countries investigated. They also found out that there exists a causal relationship between economic growth to renewable energy consumption, while some of the other countries showed traits of the opposite causality relationship. Li & Zheng (2012), in their study, showed a correlation between energy consumption and economic growth. They inferred that there exists a bidirectional causality from energy consumption to gross domestic product. They adopted the VAR model in their analysis but did not specifically work with renewable energy.

The Granger-causality test results were used by Apergis and Payne (2010) and indicated bidirectional causality between economic growth and renewable energy consumption in the short and long run for a panel of twenty OECD countries over the period 1985–2005. A panel cointegration and error correction model was used for their analysis. Using the same methods, they studied six Central American countries from 1980 to 2006 and came to the same conclusion. Unlike their previous studies mentioned above, Apergis and Payne (2012) decided to add another variable into the mix (Non-renewable energy consumption) and conducted the study for 80 countries from 1990 to 2007. The heterogeneous panel cointegration test showed a long-run equilibrium relationship between real GDP, renewable energy consumption, non-renewable energy consumption, and real gross fixed capital formation, with the respective coefficient estimates positive and statistically significant. Secondly, the panel error correction model results exhibited bidirectional causality between renewable and non-renewable energy consumption and economic growth in both the short- and long-run. They also claimed that in the short-run, renewable and non-renewable energy consumption showed signs of substitutability because of the two-way causality relationship between them in the short-run.

2.5 Green investment and Economic growth

Ahmed et al. (2022), in their paper, assumed green investment to be ‘Public investment for clean energy research, development, and demonstration (CRD & D). The results of their linear and nonlinear study showed that higher public investments in clean energy research and development-oriented projects help to curb carbon dioxide emissions in Japan. Moreover, on the other hand, this public investment increased economic growth in Japan. This study used data from the 1974–2017 period. Zhang (2022) used World Bank and OECD data to study the potential relationship between green finance, economic and environmental performance in OECD countries. Their study showed that green finance and investment bring about economic growth and generates significant positive economic output. They also argue that this green finance brings about increased environmental performance.

Zhang & Gui (2020) claimed that environmental government investment will bring about economic growth in the long-run. They went further to point out that green investment in the short-run will have a negative impact on economic growth. Hence, they conclude that there exists a positive correlation between environmental governance investment and economic growth in China. He et al. (2019) also studied the relationship between green investment and economic growth but based their study on investment multipliers. Their result showed that green investment multiplier could organically link investment, economic growth and help guide green development. They concluded that green investment affects and is necessary for economic growth.

2.6 Green investment and Carbon emissions

Bakry et al. (2023) used a panel vector error correction model (VECM) on a sample of 76 developing economies to study the long-run relationship of green finance, renewable energy, and environmental performance. Their panel cointegration analysis confirms that carbon emissions are cointegrated with green finance and renewable energy consumption. They also found green finance to be significant and reduce carbon emissions. Shen et al. (2021), in their ARDL-assisted research, set out to determine the long and short-run effects of green investment on carbon emission. They found out that green investment is negatively correlated with carbon emissions; on the other hand, there also exists a positive impact of energy consumption and financial development on carbon emissions. Luo et al. (2021) investigated the influence of green investment, technological innovations, and economic growth on carbon emissions in selected Asian countries for the period 2001 to 2019. Their study used the fully modified ordinary least square (FMOLS) and Dynamic Ordinary Least Square (DOLS). Their results indicated that green investment affects and mitigates carbon emissions.

Ganda (2018) used five proxies for environmental quality in his study. They were carbon emissions, greenhouse gases, carbon monoxide, sulphur oxides, and nitrogen oxides. He investigated green investment's impact on carbon emissions in OECD nations and pointed out that investing in green energy, such as renewable energy, improves energy efficiency while simultaneously improving environmental quality. Data from the 26 OECD countries from 2000 to 2014 and the Generalized Method of Moments (GMM) were used in his analysis. In retrospect, he concluded that green investing has a negative and statistically significant relation with these proxies for environmental quality.

2.7 Green investment and Renewable energy consumption

Zahan and Chuanmin (2021) in their study, obtained results that showed green investment as having a positive effect on clean energy consumption and a negative effect on carbon emissions in China. They, however, claim that this effect is small in the long-run. Ren et al. (2020) in their study analysed the relationship between green finance and non-fossil energy consumption. They utilized the VECM and found out that improvements in the green finance development index led to an increase in non-fossil energy use. Leonov et al. (2019), in their study, explore the linkages between GDP, GHG emissions, renewable energy consumption, and green investments, utilizing fully modified OLS (FMOLS) and Dynamic OLS. Their research estimated that green investments increase GDP per capita growth by 6.4% and increase renewable energy consumption by 5.6%.

For the other part of the divide, a study on Middle Eastern and North African countries by Charfeddine and Kahia (2019) showed that increased green financial investment had a negative impact on the use of renewable energy. Wan and Sheng (2021) utilized the simultaneous equation model and the theory behind the Environmental Kuznets Curve to dive deep into these relationships. Unlike Lyeonov et al. (2019), they directed their study to one of the world's biggest developing economies 'China.' Their study found that green investment has no significant effect on carbon emissions but a positive impact on clean energy consumption.

In summary, many scholars have suggested different relationships between carbon emissions, green investment, renewable energy consumption, and economic growth and have either confirmed or rejected them based on their empirical results. Clarity is one thing that our reviewed scholars have going for them. One of the things they are clear on is that our concepts are of global importance. While we have seen some studies that have claimed no relationship between our selected variables. Jafari et al. (2012) claimed that there exists no form of relationship; there is a consensus that at least some sort of relationship exists between them. Also, these relationships often take the same direction in the short and long run, but like general relationships, there have been studies where they differ. We will present a diagram that will help to sum up the relationships as explored by the literature in Figure 1.

The artistry and intellectual value of this literature cannot be argued about; the same does not apply to its universality. As seen from the review, most of the research done on this topic has been carried out in China or the Asian continent. This might be because of the heavy emissions being generated by the Asian continent. This is rightly pointed out by Priyan (2023) in her study; she extracted data from the IEA and showed that China is the highest emitter of GHG globally at 29% while the Asian continent tops the chart at 47%. So this might explain why the concentration of studies on this subject matter has been mostly based in Asia and China. However, to bring about a European perspective, our study is conducted in ten European countries. We have also mixed the countries between high GDP and low GDP countries.

Secondly, as it is evident from reviewed literature, ARDL seems to be the model of choice for several researchers. To deviate from the status quo, our research will be a model comparison as we made use of multiple models. The normal OLS, quadratic OLS, and Vector Autoregression (VAR) models will be used. There will also be Granger causality tests not just to determine the relationship but to take a shot at causality between the variables. These models and their outcomes will be discussed briefly in upcoming chapters.

Also going a step further in our research is the inclusion of our four variables (green investment, carbon emissions, renewable energy consumption, and economic growth). We found no literature dealt with the four phenomena together at the same time. When treated, past scholars have mostly focused on just two or three out of the four variables under study at a time. Bakry et al. (2023) and Zahan & Chuanmin (2021) in their study focused on three of the variables (green investment, renewable energy consumption, and carbon emissions). Tugcu & Menegaki (2023) and Alper & Oguz (2016) worked with two of the variables (renewable energy consumption and economic growth). In the same vein, Alaganthiran & Anaba (2022) also worked with two different variables of the four variables in our study (economic growth and carbon emissions). But as mentioned earlier, these four are some of the most important indicators of our society today (Sun et al., 2019). So, our study tries to be encompassing and covers all four of the modern-day issues of both developed and developing economies.

CHAPTER 3 : THEORETICAL FRAMEWORK

In the previous chapter, we explored a brief background and reviewed past literature on our four main concepts: 'green investment, carbon emissions, renewable energy consumption, and economic growth.' We examined what kind of relationships previous scholars have found to exist between them. This section will try to discuss some theoretical foundations behind some of the existing relationships between our variables. They include Environmental Kuznets Curve, exploring the relationship between economic growth and carbon emissions. Harrod Domar growth model, which throws light on the nexus between investment (or, in our case, green investment) and economic growth, and lastly, the Environmental Growth hypothesis. These theories individually express the sort of interaction that goes on between energy consumption and economic development. These theories will be the foundations of our models and its specification.

As an introduction, we will start with a pictorial summary of reviewed literature. This shows the relationship estimated to exist between our concepts by other scholars.

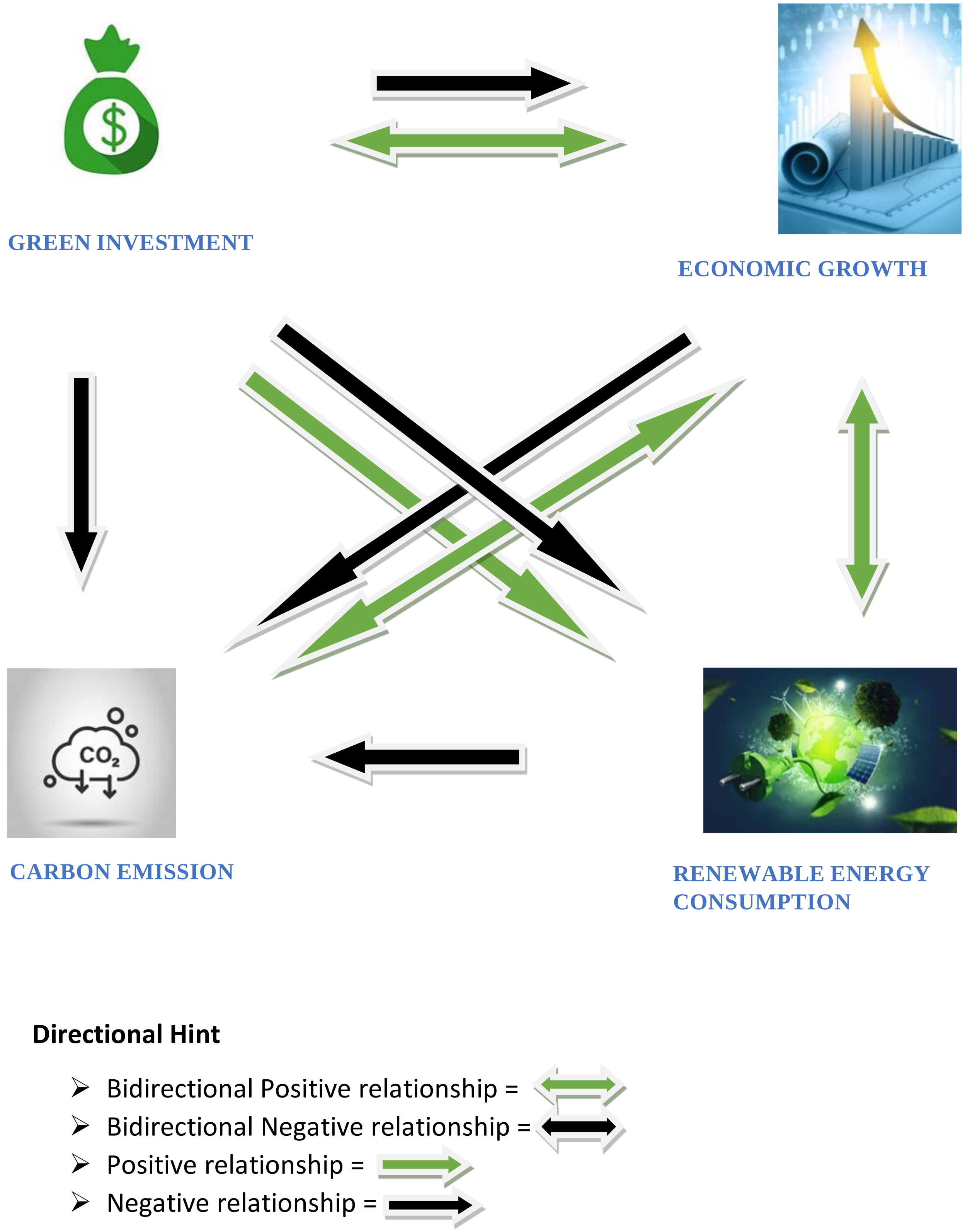

Figure 1 - Directional causal relationships between green investment, economic growth, carbon emissions, and renewable energy consumption.

3.1 Environmental Kuznets Curve

The Environmental Kuznets curve (EKC) details the nexus between per capita income and different indicators of environmental degradation. The hypothesis is that there is an inverted-U relationship between economic growth and environmental damage. The theory, in summary, posits that economic growth will lead to a reduction in environmental degradation. Explicitly it suggests that as a country's economy grows, environmental degradation increases but starts decreasing after the economy reaches a certain level of economic development.

In relation to our study, the environmental Kuznets curve could serve as one way to explain the relationship that exists between economic growth and carbon emissions. This has been put into practice many times. Alam et al. (2016) confirmed that there exists an inverted U-shaped relationship between the GDPs of Brazil, Indonesia, and China and carbon emissions with statistical significance. Wan & Sheng (2021) also in their study obtained the curve of carbon emission and per capita GDP, and it conformed to the EKC, meeting the inverted U-shaped characteristic. Mathematically expressed, they found out that, if GDP increases, the use of clean energy increases, which causes carbon emissions to reduce. There have been studies, however, where the results did not reinforce EKC, for example, in the study of Soytas et al. (2007). In their study carried out in the US from 1960 to 2004. They discovered that the relationship between GDP and carbon emissions did not support expectations as it did not display EKC properties.

Intuitively, this can also be held in extension as backing for the relationship between renewable energy consumption and carbon emissions. As pointed out by Cole, Rayner & Bates (1997), variations in output, the introduction of clean production processes, and public demand for stiff control on emissions, all lead to a reduction in environmental degradation stemming from an increase in output in the economy. Following the argument above, another hypothesis can be drawn from the EKC that economic growth leads to a positive increase in renewable energy consumption.

3.2 Harrod Domar Growth Model

The Harrod Domar growth model is an economic model that tries to explore the nexus between economic growth and investment. The model suggests that economic growth depends on savings, investment level, and capital-output ratio in the economy. The capital-output ratio was said to be the level of capital required to produce one unit of output, which can also be referred to as the efficiency of an economy (Hussein & Thirlwall, 2000). The model went further to postulate that to achieve a certain level of economic growth, a certain level of investment is needed. This level of investment was designated "Critical Investment Level" or "Harrod-Neutral rate of Growth" (Tarasov & Tarasova, 2019). When the actual level of investment goes higher than the critical investment level, the economy experiences an increased rate of growth, and the reverse is the case when the actual level of investment is lower than the critical investment rate; the economy runs the risk of a recession.

In summary, the Harrod Domar growth model points to the significance of investment in achieving economic growth. This investment and growth relationship is strengthened by the works of King & Levine (1993) and Roubini & Sala-i-Martin (1992), who insisted that investment or lack of it can bring about or inhibit economic growth. Shahbaz et al. (2013), however, seemed to be one of the few that were in the minority regarding the sort of relationship that exists between investment and economic growth, as their research of Malaysia and its economic growth from 1971 to 2011 showed a two-way causal relationship between investments and economic growth.

Intuitively, when applied to our study, this can be said to be the same with respect to green investment and its relationship with economic growth. Just like any form of investment, expectation dictates that green investment should lead to economic growth. This is supported by the work of Zhou et al. (2020), who set up a model to track the effect of green finance on economic development and specified that the development of green finance always leads to the promotion of economic growth and, ultimately, development. Further argument for this is seen as examined in our literature review of the work of Apergis & Payne (2010) when they concluded that the promotion of clean energy investments leads to economic growth. Tang & Tan 2013; He et al. 2017; and Shahbaz et al. 2019 all support this view in their studies.

3.3 Environmental Growth Hypothesis

The relationship between energy consumption and economic growth has been extensively investigated in the energy economics literature, and the objective of the pursuit has been to determine whether economic growth leads to an increase in energy consumption or vice versa.

Growth, conservation, feedback, and neutrality hypotheses are proposed to explore the nexus between economic growth and energy consumption. However, like the hypotheses, there exists a possibility of four different interactions.

3.3.1. The growth hypothesis: It is also known as the energy-led growth hypothesis, which postulates that energy consumption induces economic growth. Put differently, increases in energy consumption led to an increase in economic growth, which suggests that capital investments in the energy sector create economic growth through increasing income and creating new jobs. Wang and Wang (2020) in their study adopted this theory, and their result supported it as they found that renewable energy consumption has a positive and significant impact on economic growth. The energy-led growth hypothesis implies that a decrease in energy consumption will lead to an economic downturn; hence, countries should continue to invest in energy sectors to boost their economies. Studies that upheld this theory and still found empirical evidence supporting the hypothesis include Adhikari and Chen (2012), Tang and Shahbaz (2013), and Rezitis and Ahammad (2015).

3.3.2. The conservation hypothesis: This, on the other hand, conjectures that economic growth causes increases in energy consumption. In other words, surges in economic activities increase energy consumption. Capital investments in other sectors of the economy increase income and create new jobs and hence lead to an increase in energy consumption. This hypothesis suggests that a decline in economic growth will result in a decrease in energy consumption. Findings in Kraft and Kraft (1978), Ozturk, Aslan, and Kalyoncu (2010), and 2015 provide empirical evidence backing the conservation hypothesis.

3.3.3. The feedback hypothesis: Whereas the growth and conservation hypotheses propose unidirectional causality between economic growth and energy consumption, the feedback hypothesis postulates a bidirectional relationship between economic growth and energy consumption. The feedback hypothesis suggests that economic growth and energy consumption are strongly dependent. Capital investments in other sectors of the economy lead to an increase in energy consumption, and investments in the energy sectors induce economic development. Sbia, Shahbaz, & Hamdi (2014) and Tang and Abosedra (2014) have also found results supporting the feedback hypothesis. This hypothesis also happens to hold despite the energy source under study as recent studies by Chang et al. (2009), Constantini & Martini (2010), Lee & Lee (2010), Belke et al. (2011), and Coers & Sanders (2013) all come to the same result of bidirectional causality between non-renewable energy consumption and economic growth

3.3.4. The neutrality hypothesis: The neutrality hypothesis offers an alternative proposition postulating that there is no causal link between economic growth and energy consumption. Jafari et al. (2012) embraced this theory in their study. They tried to determine the long-run Granger causality between these variables. They used the TY (Toda Yamamoto Procedure), and their results showed that there was no relationship between these variables. According to this hypothesis, policies regarding energy sectors will have little or no effect on economic growth because energy consumption is not a significant component of overall economic activities. Studies by Soytas, Sari, and Ewing (2007) and S. T. Chen, Kuo, and Chen (2007) have found no link between economic growth and energy consumption, supporting the neutrality hypothesis. Saidi & Omri (2020) explored short and long-run analyses and found no causal relationship between carbon emissions and renewable energy consumption in the long-run, therefore, supporting the neutrality hypothesis too.

As a way of visual summary, Figure 2 explains the environmental growth hypothesis and its relationship directions as stipulated by the theory.

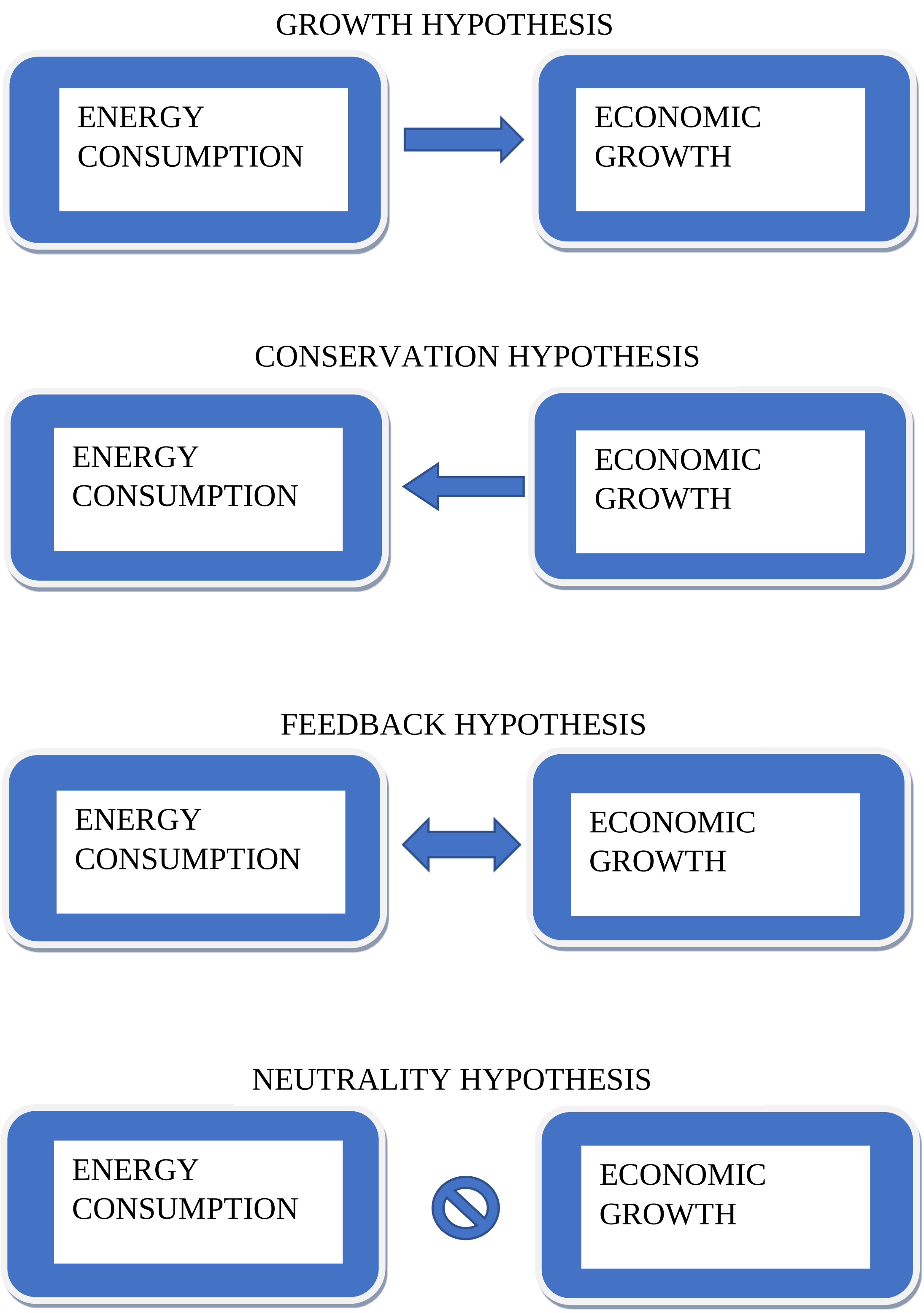

Figure 2 - Environmental Growth Hypothesis

CHAPTER 4: MATERIALS AND METHODS

This chapter includes data description and visualization, specification of econometric models, describing the statistical methods and models adopted in this thesis.

4.1 Research method and Data collection

To effectively analyse the data concerning the research question, it is crucial to identify both the data and the methodology's structure. In academic research, a thesis can fall under two categories: qualitative and quantitative (Wyse, 2011). Qualitative research pertains to data gathered through descriptions and words, which cannot be measured. On the other hand, quantitative research uses measurable data and calculations to identify statistical patterns in the primary research area. The chosen method for this thesis is quantitative research.

When describing data, we typically differentiate between primary and secondary data (Løwendahl & Wenstøp, 2008). Primary data refers to information that has been collected for their use. In contrast, secondary data is that others can still use information collected by others for their own purposes. Data can easily be categorized into qualitative or quantitative and can come from either or both sources, primary and secondary. Primary data is typically gathered through questionnaires or interviews, while databases are a common source of secondary data (Løwendahl & Wenstøp, 2008). For our thesis, we relied solely on secondary data sources from different databases.

There are a few commonly used research designs: exploratory, case studies, cross-sectional, descriptive, and causal. The entire thesis is established on a descriptive research design. According to Iacobucci & Churchill (2010), descriptive research design typically focuses on the connection between two or more variables.

4.2 Variable definitions and Data sources

This study examines the causal links between green investment (GINV), renewable energy consumption (REC), carbon emissions (CO_2), and economic growth (PGDP) of ten European Union Countries: Bulgaria, Spain, Sweden, Switzerland, Italy, Romania, Latvia, Germany, Austria, and Poland from the years 2010 to 2019.

The study area selection and time frame for this thesis are based on data availability, variables of interest, and the economic growth status of these countries. We have selected a few countries with strong economic growth as developed nations (Austria, Germany, Italy, Spain, Sweden, Switzerland), and few compared to other economically less developed or developing nations (Bulgaria, Latvia, Poland, Romania) in European Union.

We have selected four main variables and a few other control variables such as; Environmental taxes and Urban population. Moreover, we have collected data on our selected variables from different sources: Carbon emissions, Renewable energy consumption, Gross Domestic Product per capita, Government expenditure on education, and Urban population were collated from the World Bank's World Development Indicator online database. Data on Green investment and Environmental tax are taken from the Eurostat database.

Below we present and describe all the variables according to our research purpose and data collection methods.

Carbon emissions (CO_2):

According to the World Bank's WDI, carbon emissions are mainly caused by the by-products of production and energy use. Carbon emissions are also responsible for the increase of greenhouse gases that raise global warming. In this thesis, we collected carbon emissions data from the World Bank`s WDI. According to the World Bank (2023), the data on CO_2 emissions include the gases that are output from cement manufacture and fossil fuel burning. However, it excludes the emissions from land use, for example, deforestation. Moreover, we have extracted the carbon dioxide per capita (CO_2) data of selected European countries annually from the years 2010 to 2019.

Renewable energy consumption (REC): The amount of each country's renewable energy consumption in total final energy consumption is presented by this variable; Renewable energy consumption, in this thesis. The data on Renewable energy consumption (REC) is collected from the World Bank`s WDI for our selected European countries annually for our selected period of study.

Green Investment (GINV): Drawing from the words of Sharif et al. (2023) and Musah et al. (2022), we are pointing to the importance of green investment in environmental protection and sustainable economic growth. According to Liao and Shi (2018), Green investment (GINV) reflects the proportion of GDP regained from the investment in different efforts to control environmental pollution. However, we assume the role of green investment is to decrease carbon emissions and improve clean energy consumption through production and consumption activities (Datta 2017a, b; Wang et al., 2020b).

Due to the availability of data and our research interest, in this thesis, we adopt that green investment refers to Environmental protection investments of the total economy and the data of selected European countries collected from the Eurostat database from the year 2010 to 2019.

Gross Domestic Product per capita (PGDP): According to the World Bank collection of development indicators, Gross domestic product (GDP) per capita expressed in current international dollars is converted by the conversion factor purchasing power parity (PPP), which we have presented as the Economic Growth variable. Gross domestic product (GDP) is the total gross value added by all resident producers in a country added with all product taxes also minus all subsidies that are not included in the value of the products. The Gross Domestic Product (PGDP) data is collected annually from the World Bank`s World Development Indicator online database for our selected European countries for our study period.

We have combined previous research and our research area of interest and included some controlled variables in our analysis to minimize the errors that omissions of variables might cause.

Our selected control variables are as follows:

Environmental taxes (ETAX): We have extracted data on environmental tax revenue from Eurostat, which includes tax from energy, pollution, transportation, and resource taxes. According to Eurostat, Environmental taxes (ETAX) are broken down by economic activity using the European Union classification of economic activities in Nomenclature of Economic Activities (NACE) for production activities, adding households and non-residents. Data are annual and unit of measure in a million euros.

Government expenditure on education (GEDU): This term refers to the amount of money that the government (at the local, regional, and national levels) spends on education in the country. It is typically expressed as a percentage of the country's overall GDP. Government expenditure on education (GEDU) data is collected from the World Bank`s WDI online database and includes our selected European country’s annual percentage spent on education over GDP from 2010 to 2019.

Urban population (UP): Generally, people living in urban areas are called urban populations. National statistical offices have also mentioned this. According to the World Bank's WDI (2023), a country's population is divided into urban and rural populations. Urban population is the proportion of people living in an area classified as 'urban' as a percentage of the total population. The urban population has a significant impact on a country's economic growth. The urban population (UP) variable's data is extracted from the World Bank`s WDI online database for our selected European countries annually from the study period.

4.2.1 Data description

Here, we listed all our selected variables for the analysis and mentioned their sources.

Variables	**Symbol**	**Definition, the unit of measure, and Time**	**Data sources**
Carbon emission	CO_2	Emission of carbon dioxide (metric tons per capita), Annual	WORLD BANK's WDI database.
Renewable energy consumption	REC	Renewable energy consumption (% of total final energy consumption), Annual	WORLD BANK's WDI database.
Green Investment	GINV	Environmental protection investments of total economy (Million euro), Annual.	Eurostat

Gross Domestic Product per capita	PGDP	GDP per capita, PPP (current international $), Annual.	WORLD BANK's WDI database.
Environmental taxes	ETAX	Environmental taxes by economic activity(Million euro), Annual.	Eurostat
Government expenditure on education, total (% of GDP)	GEDU	Government expenditure on education, total (% of GDP), Annual.	WORLD BANK's WDI database.
Urban population	UP	Urban population (% of the total population), Annual	WORLD BANK's WDI database.

Table 1 - Data description, symbols, measurements unites and sources

4.2.2 Data visualization

The graphical visualization of all the major variables, carbon emissions (CO_2), renewable energy consumption (REC), green investment (GINV), and gross domestic product per capita (PGDP), are shown in the figures below.

In all figures, Y-axis presents all the variables with measurement units, and X-axis represents the selected Countries for this study.

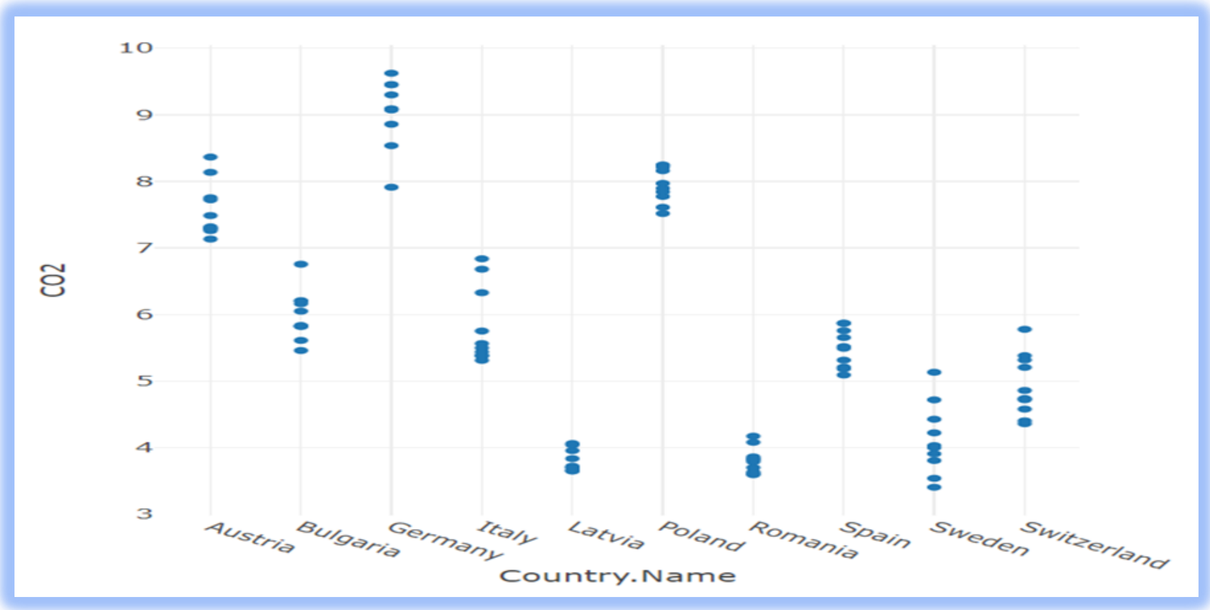

Figure 3 - Carbon emissions in metric tons per capita, annually

In Figure 3, the Y-axis represents 'CO_2' as Carbon emissions in metric tons per capita annually, and the X-axis represents all the countries. There exist significant differences between the amount of CO_2 emissions per capita among all the selected countries. Germany shows the highest while Latvia and Romania present the lowest amount of per capita carbon emission.

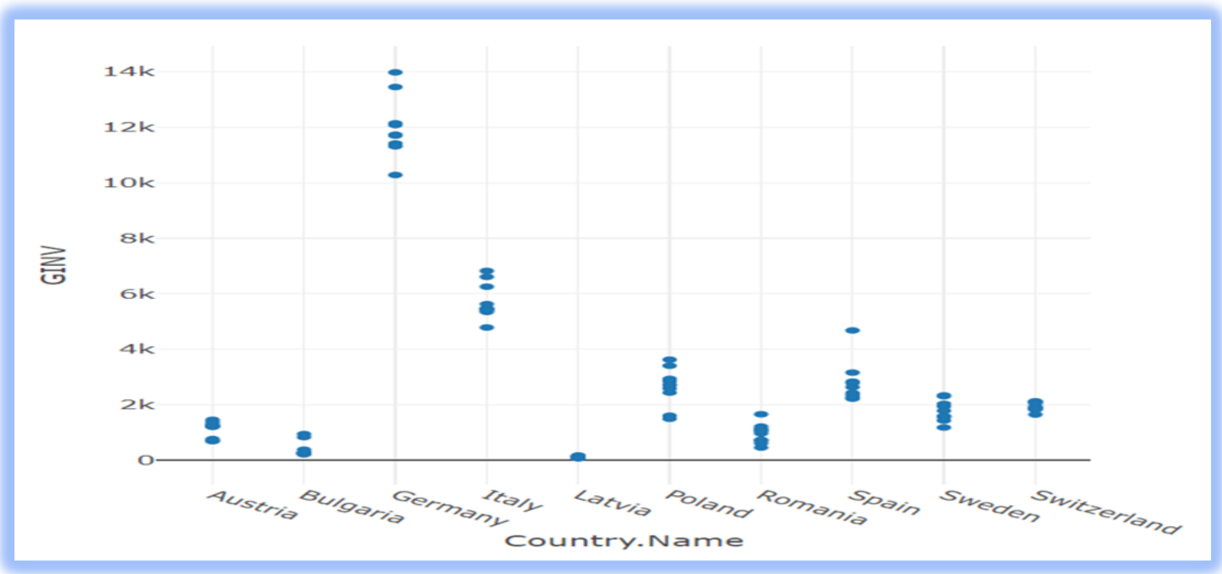

Figure 4 - Green investments of the total economy in a million euros

In Figure 4, Y-axis represents green investment (GINV), which is the Environmental protection investment of the total economy in a million euros annually, and X-axis represents all the countries. Here, GINV in Germany shows the highest. On the other hand, the lowest environmental protection investments are seen in Latvia and Bulgaria. This shows Germany has high carbon emissions per capita, and also invested highly to protect the environment.

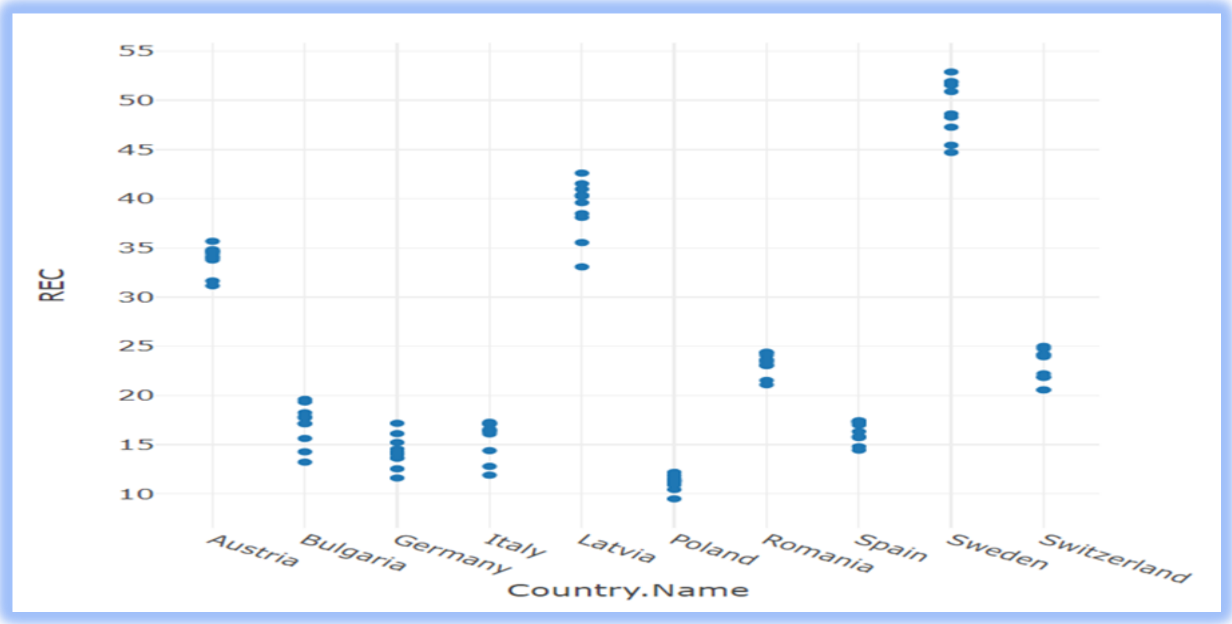

Figure 5 - Renewable energy consumption (% of total final energy consumption)

In Figure 5, Y-axis represents REC, Renewable energy consumption (% of total final energy consumption) annually; like others, X-axis represents all the selected countries. The major difference from the previous variables, CO_2 emissions and GINV, is that the amount of REC is the highest in Sweden, Latvia, and Austria. At the same time, Poland, Spain, and Italy indicate the lowest percentage of renewable energy consumption annually from total final energy consumption.

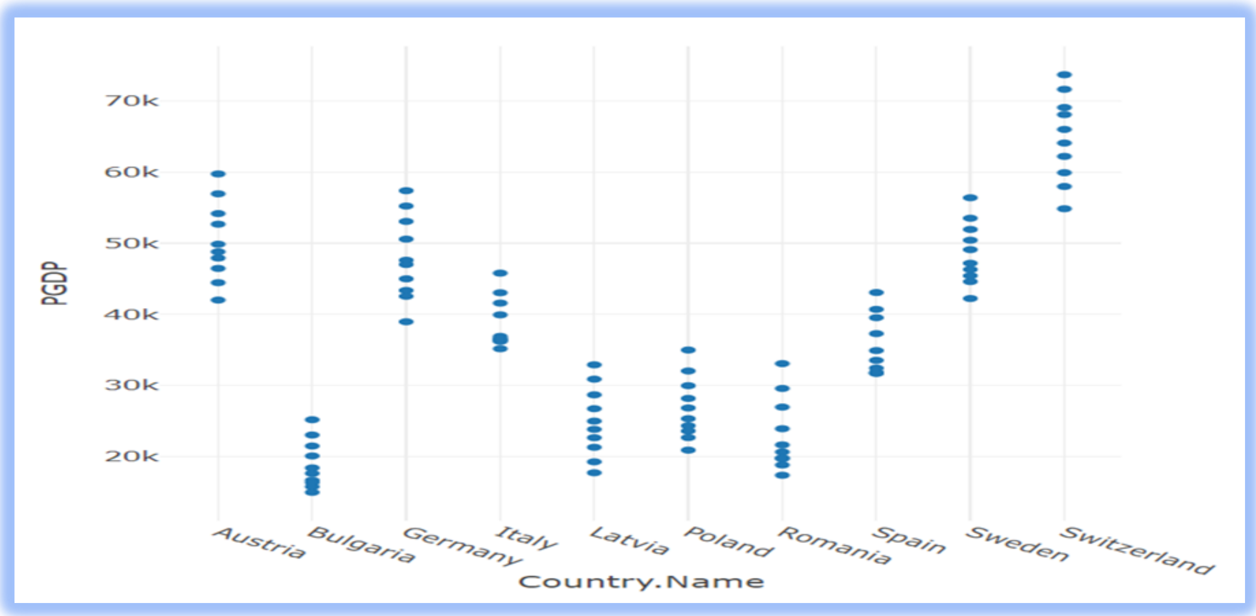

Figure 6 - Real GDP per capita, at PPP (Purchasing Power Parity)

In this Figure 6, Y-axis represents PGDP, real GDP per capita, at PPP. The X-axis represents all the selected countries. The economic growth variable PGDP shows a totally different phenomenon; PGDP shows the highest in Switzerland, Austria, and Sweden, while Bulgaria, Latvia, and Romania show the lowest among these countries. This figure gives us a clear idea of these selected country's economic growth levels considering the PGDP.

4.3 Econometric models

The main objective of exploring the causal links between these variables is to understand how policies and actions related to green investment and renewable energy consumption can impact Carbon emissions and economic growth. For example, suppose green investment (GINV) and renewable energy consumption (REC) lead to a reduction in carbon emissions. In this case, policymakers may promote REC to mitigate climate change. Similarly, suppose green investment and renewable energy consumption are found to have positive effects on economic growth. In that case, policymakers will encourage these activities to achieve sustainable economic development.

There are various statistical techniques to explore the causal links between these variables, such as structural equation modelling, regression analysis, vector auto-regressive model (VAR), Autoregressive distributed lag model (ARDL), and Granger causality tests. These techniques can help to identify whether there is a causal relationship between the variables and, if so, in what direction. Previous studies conducted by Wang et al. (2022), Wan et al. (2022), Kónya (2006), and Zeb et al. (2014) used regression analysis, vector autoregression (VAR), and the Granger causality test for their analysis. Regression analysis can be used to estimate the impact of green investment and renewable energy consumption, and carbon emissions on economic growth. At the same time, the Granger causality test can analyse the direction of causality between the variables. Furthermore, these statistical test results will help policymakers to understand the rational effect and importance of the causal relationship between these variables. We are using the linear and quadratic regression analysis, the VAR model, and Granger causality tests to estimate and investigate the relationship and causality among the key variables of our study (green investment, carbon emissions, renewable energy consumption, economic growth).

4.3.1 Specification of econometric models

To illustrate the relationship impact of the selected variables, we have used regression models, which was also done by Liu et al. (2020b) in their research paper. Further in our thesis, we work with simultaneous regression models with different explanatory variables.

In every equation, subscript ‘t’ represents the year, and the error term ‘ ϵ ’ is also included. We have also done the logarithm transformation of all variables for analysis.

Simultaneous equations for regression models are:

The Linear models.

1. $CO_{2t} = \omega 0 + \omega 1 REC_t + \omega 2 GINV_t + \omega 3 PGDP_t + \omega 4 ETAX_t + \omega 5 GEDU_t + \omega 6 UP_t + \epsilon_t$

2. $REC_t = \partial 0 + \partial 1 CO_{2t} + \partial 2 GINV_t + \partial 3 PGDP_t + \partial 4\, ETAX_t + +\partial 5 GEDU_t + \partial 6 UP_t + \epsilon_t$

3. $GINV_t = \beta 0 + \beta 1 CO_{2t} + \beta 2 REC_t + \beta 3 PGDP_t + \beta 4\, ETAX_t + \beta 5 GEDU_t + \beta 6 UP_t + \epsilon_t$

4. $PGDP_t = \gamma 0 + \gamma 1 CO_{2t} + \gamma 2\, REC_t + \gamma 3 GINV_t + \gamma 4\, ETAX_t + \gamma 5 GEDU_t + \gamma 6 UP_t + \epsilon_t$

The Quadratic models.

The squared term of gross domestic product per capita (PGDP) as; $PGDP^2$ and the squared term of green investment (GINV) as; $GINV^2$ is introduced in the quadratic models for our study.

5. $CO_{2t} = \omega 0 + \omega 1REC_t + \omega 2GINV_t + \omega 3GINV_t^2 + \omega 4PGDP_t + \omega 5PGDP_t^2 + \omega 6ETAX_t + \omega 7GEDU_t + \omega 8UP_t + \epsilon_t$

6. $REC_t = \partial 0 + \partial 1CO_{2t} + \partial 2GINV_t + \partial 3GINV_t^2 + \partial 4PGDP_t + \partial 5PGDP_t^2 + \partial 6\,ETAX_t + \partial 7GEDU_t + \partial 8UP_t + \epsilon_t$

7. $GINV_t = \beta 0 + \beta 1CO_{2t} + \beta 2REC_t + \beta 3PGDP_t + \beta 4PGDP_t^2 + \beta 5ETAX_t + \beta 6GEDU_t + \beta 7UP_t + \epsilon_t$

8. $PGDP_t = \gamma 0 + \gamma 1CO_{2t} + \gamma 2REC_t + \gamma 3GINV_t + \gamma 4GINV_t^2 + \gamma 5ETAX_t + \gamma 6GEDU_t + \gamma 7UP_t + \epsilon_t$

Description of linear and quadratic models:

Equation (1) studies the impact of renewable energy consumption (REC), green investment (GINV), economic growth (PGDP), and other control variables on carbon emissions (CO_2). The equation (5) is rooted in the EKC theoretical hypothesis (Grossman & Krueger, 1994), which proposes that economic growth's related to carbon emission. Previous research by Dinda et al.(2004) and Shahbaz et al. (2013) both include the primary and squared terms of GINV, and PGDP to justify the Environmental Kuznets Curve establishment. However, economic growth could affect environmental quality improvement through its scale, technical, and structural situations.

Equation (2) explores the linear impact of carbon emissions, green investment (GINV), economic growth (PGDP), and some control variables on renewable energy consumption (REC). This equation is implicit Environmental Kuznets curve hypothesis. On the other hand, Environmental growth hypothesis proposes unidirectional causality as well as neutrality between economic growth and energy consumption. According to the Environmental growth hypothesis, economic growth can cause an increase in energy consumption. In our research, we relate renewable energy consumption with economic growth, whereas EKC relates to carbon emission and economic growth.

The equation (6) regression model includes the primary and squared term of per capita GDP, and GINV with other independent and control variables of equation (2). However, in equation (6) we considered the environmental growth conservation hypothesis that is decline in Economic growth causes decrease in renewable energy consumption.

In equation (3), green investment (GINV) is dependent on renewable energy consumption (REC) and carbon emissions (CO_2) on economic growth (PGDP). Moreover, previous research by Shahbaz et al. (2013) on investment and economic growth showed a unidirectional relationship between them. Concerning the previous studies, we have developed equation (7), where we have taken the secondary term of PGDP to see the effect of primary and squared GDP per capita on GINV.

The explained variable of equation (4) is examined to identify the linear impact of green investment (GINV), renewable energy consumption (REC), and carbon emissions (CO_2) on economic growth (PGDP). According to the environmental growth hypothesis, investing in the energy sector can lead to economic growth. In equation (8), is following Harrod Domar's growth model, according to the Hussein & Thirlwall (2000) the Harrod Domar model analysis the fact that achieving a certain level of economic growth depends on a certain level of investment. Also, we consider the primary and quadratic term of green investment and understand the dynamic between improving environmental protection investment and economic development.

4.4 Regression analysis

To study the relationship among the key variables (green investment, carbon emissions, renewable energy consumption, and economic growth), we have constructed simultaneous equations composed of regression models (e.g.,Chandrashekar Raghutla et al. 2021, and Liu et al. 2020b). As developing single model is difficult for our analysis as it may cause endogeneity. For example, renewable energy consumption, and carbon emissions variables may have impact on Gross domestic product per capita, so two or more variables can affect the same one. Therefore, we have established a simultaneous equation composed of regression models.

4.5 Vector Autoregression model (VAR)

We employed Vector Autoregression (VAR) econometric model for the data analysis. This model is used for time series analysis but has some crucial differences from other models such as Autoregressive Distributed Lag (ARDL) or Non-Linear Autoregressive Distributed Lag (NARDL). There is no one-size-fits-all answer to which model is superior, as it depends on the specific research question and the data available. When deciding between VAR and other models, we give importance to analyse and consider the research question and data characteristics since all methods have pros and cons. VAR is a flexible model that can accommodate a wide range of economic variables and can capture dynamic interactions among them. It can be used to forecast and simulate economic variables and to conduct policy analysis**.** Many research studies (e.g., Wang et al., 2022, Wan et al., 2022, and Zeb et al., 2014) used VAR econometric model to capture dynamic interactions and forecast between multiple variables.

VAR is a model that describes the relationships among multiple variables in a system. It is a statistical model that estimates the joint dynamics of a set of variables, where each variable in the model can be explained by its past values and the past values of other variables in the system (Lütkepohl, H. (2013), page 139).

The mathematical format of VAR is a basic form of a model with p lags VAR(P).

$$Yt = c + A1Yt\text{-}1 + A2Yt\text{-}2 + ... + ApYt\text{-}p + e\_t$$

Here, 'Yt' is a vector of variables at time 't', 'c' is a vector of constant terms, A is matrices of coefficients, 'p' is the number of lags, and 'e_t' is a vector of error terms.

4.6 Granger Causality test

A Granger causality test is used to identify the direction of causality between variables. Understanding the causal direction between green investment, carbon emissions, economic growth, renewable energy consumption, and other control variables is vital to the research as it can influence climate change and sustainable development policymaking. We read through a lot of scientific articles, such as Friston et al. (2014), Peng et al. (2016), and Kónya (2006), using Granger for the causality analysis to identify the causal link and causal direction between the selected variables for their study. For example, in our thesis, we want to investigate if carbon emissions granger causes economic growth or vice versa. So, here granger causality testing will provide us directional causality information about CO_2 variable for predicting the PGDP variable.

CHAPTER 5 : EMPERICAL RESULTS AND DISCUSSIONS

In this chapter, we will present all the analysis results and a detail discussion of the findings. Firstly, we examine the descriptive statistics, and correlation analysis. Further we conducted unit root test, linear and quadratic regressions, VAR model and lastly the Granger causality test.

5.1 Descriptive Statistic

The descriptive statistical results of the all the selected variables of our thesis are shown in Table 2.

Statistic	N	Mean	St. Dev.	Min	Max
CO_2	100	1.721	0.303	1.225	2.264
REC	100	3.077	0.468	2.250	3.968
GINV	100	7.309	1.311	4.275	9.545
PGDP	100	10.465	0.413	9.613	11.208
ETAX	100	9.022	1.356	6.274	11.020
GEDU	100	1.547	0.223	1.086	2.034
UP	100	4.239	0.143	3.986	4.474

Table 2 - Descriptive statistics table

This descriptive statistic results present the basic information about the data we have extracted.

As presented in Table 2, PGDP (10.465), (11.208) and GINV (7.309), (9.545) has the highest mean and max value while the REC (3.077), (3.968) and CO_2 (1.721), (2.264), are less in comparison. However, GINV (1.311) has the highest standard deviation followed by REC (0.468), PGDP (0.413), and CO_2 (0.303) in a descending order.

5.2 Correlation Analysis

The statistical method aims to identify any correlation between multiple variables or datasets and measure the intensity of that correlation. A correlation analysis can result in three possible outcomes. A positive correlation indicates a score ranging from +0.5 to +1, which means that both variables increase simultaneously, and there is a strong positive correlation.

When two variables have a negative correlation, a score ranging from -0.5 to -1 indicates a strong negative correlation. However, this indicates that if one variable decreases, the other variable will decrease proportionally. A score of 0 unequivocally indicates the absence of any correlation or means no connection between the variables.

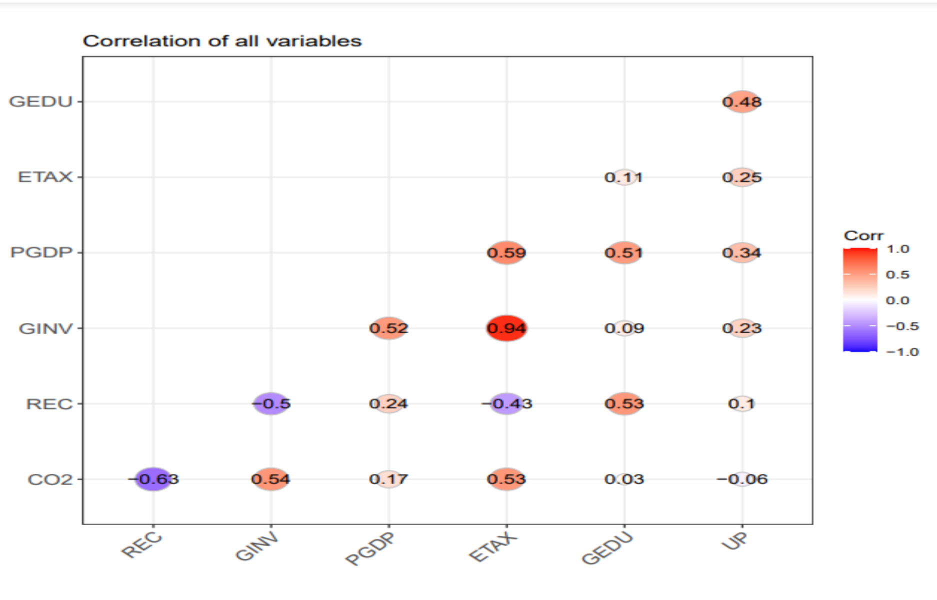

Figure 7 - Correlation of all variables

The correlations overview validates that all the major variables; green investment, renewable energy consumption, carbon emissions, and economic growth are related and correlated either positively or negatively.

Based on the results of the correlation analysis, it is evident that carbon emissions (referred as CO2 in figure 7) is positively correlated with GINV and PGDP. This indicates that these variables will increase simultaneously, suggesting a strong positive correlation. Conversely, a highly negative correlation between carbon emission and renewable energy consumption indicates that if renewable energy consumption increases, carbon emissions will decrease significantly and vice-versa. We also see that the PGDP has a higher positive correlation with GINV. However, correlations exist among control variables, ETAX, GEDU, and UP, with all other variables either positive or negative.

5.3 Econometric Analysis

5.3.1 Unit root test

To ensure accurate and unbiased results, it is necessary to conduct a unit root analysis or data stationarity test to avoid biased regression. In our paper, we used the Augmented Dickey fuller test (ADF) and Levin Lin Chu (LLC) test to carry out the panel data unit root test to identify the issue of the stationarity. This test analyses the correlation among forecast Y values with time-lagged and lagged difference terms.

If the p-value obtained from the ADF and LLC stationarity test is lower than 0.05, we can reject the null hypothesis or dismiss the assumption of unit root based on the test results. This will imply that the data sequence is stable or stationary. Conversely, if the analysis's result shows a p-value higher than 0.05, then our data sequence is nonstationary, which means we cannot reject the null hypothesis.

To check for stationarity between our variables, then we conducted the ADF and LLC tests. The results of the ADF and LLC tests on all the selected variables are shown in Table 3 below.

Variables	**ADF** (Dickey-fuller values)	**LLC** (Z- values)	**Decision**
CO_2	-5.0903	-3.7748	stationary
REC	-9.0199	-11.644	stationary
GINV	-10.123	-5.4307	stationary
PGDP	-6.6869	1.2305	Non- stationary
ETAX	-10.846	-7.7748	stationary
GEDU	-8.5199	-1.9712	stationary
UP	-9.1715	-5.9317	stationary

Table 3 - Stationarity test results

ADF test result shows all the variables are stationary at I(0). So based on the ADF test results, we can reject the null hypothesis or dismiss the assumption of a unit root for all the variables. On the other hand, the LLC test showed a higher P-value for PGDP.

5.3.2 Regression results and discussion

This part analyses and discuss the regression results of simultaneous equation models (1)-(8). Equations (1)-(4) are linear models, and equations (5)-(8) are quadratic models. With this regression analysis, we have analysed the interaction between carbon emission, renewable energy consumption, green investment, and economic growth of our thesis's selected countries from 2010 to 2019.

Tables 4 and 5 show regression results obtained by estimating simultaneous equation models (1)-(8). Further, we interpret and discuss the regression analysis findings of all the equations in detail.

Variables	(1)	(2)	(3)	(4)
Dependent variables	CO_2	REC	GINV	PGDP
CO_2		-0.755*** (0.080)	-0.346 (0.220)	0.257** (0.106)
REC	-0.634*** (0.055)		-0.730*** (0.163)	0.598*** (0.073)
GINV	-0.065 (0.044)	-0.163*** (0.050)		0.047 (0.056)
PGDP	0.142* (0.078)	0.394*** (0.097)	0.140 (0.136)	
ETAX	0.059 (0.045)	0.015 (0.052)	-0.814*** (0.056)	0.189*** (0.050)
GEDU	0.799*** (0.121)	1.013*** (0.135)	0.743** (0.299)	0.063 (0.136)
UP	-0.654*** (0.186)	-0.594*** (0.182)	-0.323 (0.399)	0.221 (0.145)
Constant	3.658*** (0.776)	2.264* (1.149)	1.568 (2.050)	5.099*** (0.708)
R^2	0.673	0.837	0.907	0.682
Adjusted R^2	0.652	0.826	0.901	0.662
Residual Std. Error	0.179	0.195	0.413	0.413
F Statistic	31.942***	79.592***	151.141***	33.258***

Table 4 - Linear Regression results

Note: Significance level *p<0.1; **p<0.05; ***p<0.01. This table firstly present the ‘Estimate’ values with significance level, and the ‘Standard error’ in parenthesis for all the variables. (Estimated by ‘R’ studio)

Table 4 represents the estimated results of the simultaneous equations (1)-(4). Columns (1-4) show the causal relationship between carbon emissions, renewable energy consumption, green investment, and economic growth.

In column (1) of CO_2 emissions equation, GINV has non-significant impact on CO_2 and PGDP. On the other hand, renewable energy consumption is (-0.634***) negative and highly significant, at a 1% level. Usman at al. (2020) study also found a negative impact of REC on CO_2. However, we found that the degree of development in green investment decreases carbon emissions but is statistically non-significant. Similarly, a previous study concerning causality among carbon emissions and green investment done by Wan et al. (2022) also found that green investment has a negative impact but non-significant on carbon emissions.

In column (2) of REC equation, all the core variables are statistically significant to the dependent variable. The research paper by Radmehr et al. (2021) on EU countries employed the panel spatial simultaneous equations models, and their findings support the link between renewable energy, carbon emissions, and economic growth in EU countries between 1995 to 2014.

In column (3) of GINV equation, CO2, and PGDP variables have no significant impact on GINV. However, REC is (-0.730***) is negative and highly significant to GINV. Moreover, we can also see a significant and negative impact of green investment (-0.163***) on renewable energy consumption in column (2).

In column (4) of PGDP equation, green investment (0.047) has no significant impact on economic growth, unlike other core variables. As we can see, all the hypotheses are untrue as many core variables are insignificant to dependent variables. Additionally, many control variables are also not statistically significant to dependent variables.

Variables	(5)	(6)	(7)	(8)
	CO_2	REC	GINV	PGDP
CO_2		-0.759*** (0.091)	-0.347* (0.208)	0.297*** (0.103)
REC	-0.608*** (0.051)		-0.466*** (0.165)	0.591*** (0.073)
GINV	-0.316** (0.123)	-0.215* (0.128)		0.314** (0.148)
$GINV^2$	0.018** (0.008)	0.005 (0.009)		-0.021** (0.009)
PGDP	-3.030 (3.740)	1.760 (3.619)	-34.927*** (6.377)	
$PGDP^2$	0.151 (0.179)	-0.064 (0.173)	1.660*** (0.300)	
ETAX	0.076 (0.071)	-0.010 (0.070)	1.024*** (0.059)	0.210*** (0.049)
GEDU	0.818*** (0.126)	1.000*** (0.139)	0.916*** (0.244)	0.034 (0.132)
UP	-0.755*** (0.191)	-0.604*** (0.193)	-0.616* (0.338)	0.331* (0.173)
Constant	21.285 (19.504)	-4.569 (19.035)	184.736*** (33.216)	3.662*** (1.082)
R^2	0.690	0.838	0.936	0.692
Adjusted R^2	0.662	0.823	0.931	0.668

Residual Std. Error	0.176	0.197	0.344	0.238
F Statistic	25.275***	58.698***	191.920***	29.514***

Table 5 - Quadratic regression results.

Note: Significance level *p<0.1; **p<0.05; ***p<0.01. This table firstly present the 'Estimate' values with significance level, then the 'Std. error' in parenthesis for all the variables. (Estimated by 'R' studio)

Further, we have decided to follow the environmental Kuznets theory, and we took the squared term of GDP per capita and also introduced the squared term of green investment (GINV) for our study. Table 5 represents the estimated results of the quadratic models from equations (5)-(8).

In column (5): renewable energy has (-0.608***) a negative and significant impact (significant at the 1 % level) CO_2 emissions. This means that if renewable energy consumption increases, CO_2 emissions will decrease for the selected EU countries. We can also see that green investment's primary and squared terms (-0.316**, 0.018**) have negative and positive impact respectively on CO_2 emissions and are also significant at 5%. Conversely, the economic growth variable showed no significant impact, and the primary and squared terms of the economic growth variable are negative and positive respectively. There is a U-shaped relationship that exists between economic growth and carbon emission, but that is statistically non-significant. This equation (5) estimation results present no properties that support the Environmental Kuznets curve hypothesis. The previous study by Soytas et al. (2007) also didn't find any EKC theory support properties between the income growth and carbon emissions of The United States. Our selected countries for this study also do not support the EKC theory. Bradford et al. (2005), in their study, also conclude their findings as the presence of EKC is not included in all pollutants.

In column (6): firstly, we can see that carbon emissions is statistically significant and has a negative impact on renewable energy consumption. A 1% increase in carbon emissions will affect renewable energy consumption negatively by 0.759. In their paper, Bilgili et al. (2016) studied the causality between renewable energy and carbon emissions within the EKC model. Their findings support a negative causal relationship between renewable energy consumption and carbon emissions. This is also supported by our estimation results in columns (5) and (6) of Table 5.

The primary and squared terms of PGDP (1.760), and (-0.064) are positive and negative, respectively, but they are statistically non-significant on REC. Thus, we cannot consider the selected country's income level or GDP growth to have a significant impact on renewable energy consumption.

Column (7) presents the estimation results for GINV. We found that all the core variables are statistically significant to the dependent variable. GDP per capita's primary and squared terms have significant negative (-34.927***) and positive (1.660***) impacts on green investment. The reason could be that a large sum of money invested in the short term for environmental protection may negatively influence economic growth, while in the long run, will return positive growth to the nation's economy. A study by Lyeonov et al. (2019) on European Union countries during the period 2008-2016 found a significant relation between greenhouse gas emissions, green investment, and per capita GDP.

In column (8), PGDP is significantly related to all the core variables. The primary and squared term for GINV has positive and negative impact (both terms are significant at a 5% level). CO_2 emissions also has a positive and significant (0.297*** at a 1% level) impact on GDP; this means an increase in carbon emissions will impact an increase in economic growth. Begum et al. (2015) in their study also found a positive relationship between carbon emissions and economic growth. Moreover, they confirmed that the hypothesis of EKC for their sample country is not valid for the study time duration.

5.4 VAR analysis and Discussion

In this figure 12, the estimated result from VAR model is being presented. It includes the time trend over 2010 to 2019 (X- axis) for all our selected variables (Y-axis).

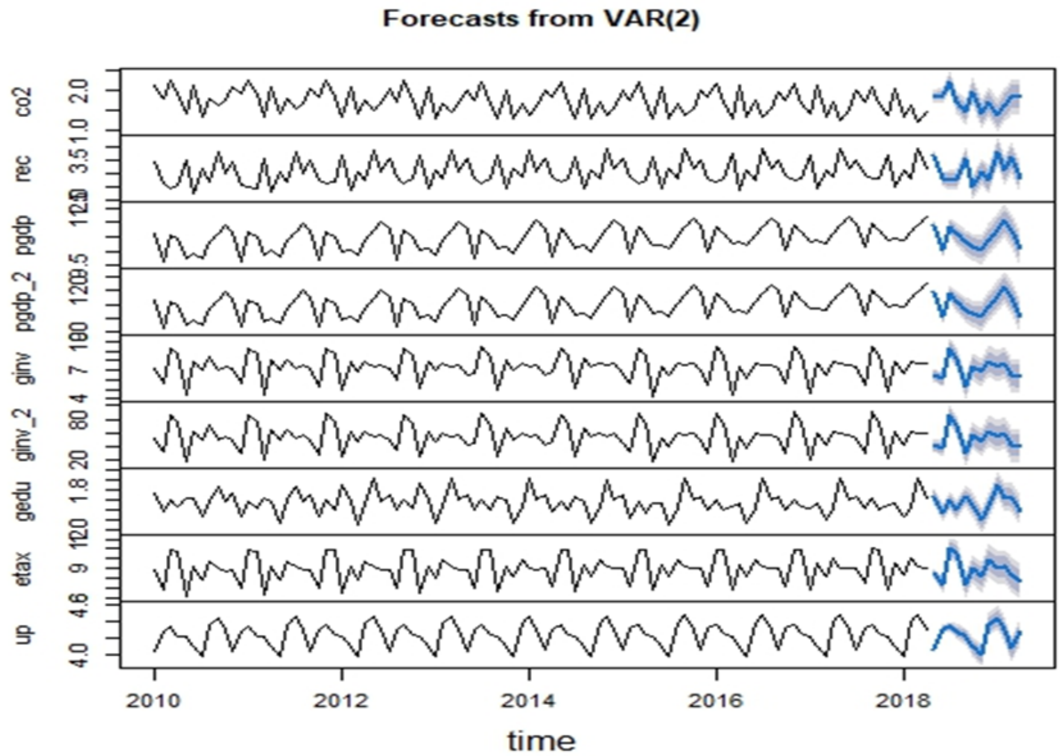

Figure 8 - Variable forecast from VAR model

Variable Name	Renewable energy Consumption			Carbon dioxide Emission		
	Coefficient	Std Error	t-statistics	Coefficient	Std Error	t-statistics
CO_2.L1	-0.434650**	0.128671	-3.378	0.552542***	0.086456	6.391
CO_2.L2	-0.700241***	0.154153	-4.543	0.750296***	0.103577	7.244
GINV.L1	0.947463***	0.131207	7.221	-0.212668*	0.088160	-2.412
$GINV^2$_.L1	-0.069947***	0.009477	-7.380	0.013954*	0.006368	2.191
GINV.L2	0.125060	0.213927	0.585	0.121458	0.143741	0.845
$GINV^2$_ .L2	-0.001252	0.016139	-0.078	-0.010439	0.010844	-0.963
REC.L1	-0.513917***	0.134111	-3.832	0.166866.	0.090111	1.852
REC.L2	0.207556	0.149992	1.384	0.473410***	0.100782	4.697

PGDP.L1	-0.146418	2.422880	-0.060	-5.279626**	1.627969	-3.243
$PGDP^2$_. L1	0.010738	0.117759	0.091	0.284026***	0.079124	3.590
PGDP.L2	3.721202.	2.040435	1.824	- 9.290948***	1.370999	-6.777
$PGDP^2$_.L2	-0.179199.	0.096885	-1.850	0.415075***	0.065099	6.376
ETAX.L1	0.281853***	0.058487	4.819	- 0.263773***	0.039298	-6.712
ETAX.L2	0.140894*	0.065940	2.137	0.156923***	0.044306	3.542
GEDU.L1	0.061927	0.141719	0.437	-0.171548.	0.095223	-1.802
GEDU.L2	0.019878	0.159562	0.125	-0.036107	0.107212	-0.337
UP.L1	0.353364	0.229057	1.543	0.008083	0.153907	0.053
UP.L2	-0.785579.	0.443128	-1.773	-0.339940	0.297744	-1.142
MULTIPLE R2	0.9662			0.9634		
ADJUSTED R2	0..9585			0.9551		
P-VALUE	<2.2e-16			<2.2e-16		
F TEST	125.4			115.5		

Table 6 - VAR model results 1

Note: Significance levels: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 (model estimated by 'R' studio)

Variable Name	Green Investment			Per Capita Gross Domestic Product		
	Coefficient	Std Error	t-statistics	Coefficient	Std Error	t-statistics
CO_2.L1	-1.16103*	0.48156	-2.411	- 0.966578***	0.108299	-8.925
CO_2.L2	2.66644***	0.57693	4.622	0.950189***	0.129747	7.323
GINV.L1	- 2.19717***	0.49105	-4.474	0.451133***	0.110435	4.085
$GINV^2$_.L1	0.16434***	0.03547	4.633	- 0.029870***	0.007977	-3.745

GINV.L2	0.25691	0.80064	0.321	-0.710451***	0.180058	-3.946
$GINV^2$_ .L2	-0.04199	0.06040	-0.695	0.049851***	0.013584	3.670
REC.L1	0.83588.	0.50192	1.665	0.221135.	0.112878	1.959
REC.L2	0.24613	0.56136	0.438	0.198199	0.126245	1.570
PGDP.L1	0.54346	9.06783	0.060	2.316562	2.039287	1.136
$PGDP^2$_. L1	0.02498	0.44072	0.057	-0.065189	0.099115	-0.658
PGDP.L2	-7.57488	7.63650	-0.992	-0.433366	1.717391	-0.252
$PGDP^2$_.L2	0.33221	0.36260	0.916	0.017448	0.081546	0.214
ETAX.L1	-0.69214**	0.21889	-3.162	-0.171543***	0.049228	-3.485
ETAX.L2	-0.63303*	0.24679	-2.565	-0.270995***	0.055500	-4.883
GEDU.L1	-0.54072	0.53040	-1.019	-0.599641***	0.119282	-5.027
GEDU.L2	0.77055	0.59717	1.290	0.062846	0.134300	0.468
UP.L1	3.96698***	0.85727	4.627	2.491477***	0.192793	12.923
UP.L2	-3.04875.	1.65844	-1.838	-1.097726**	0.372971	-2.943
MULTIPLE R2	0.9394			0.9682		
ADJUSTED R2	0.9256			0.961		
P-VALUE	<2.2e-16			<2.2e-16		
F TEST	68.08			133.8		

Table 7 - VAR model results 2

Note: Significance levels: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 (model estimated by 'R' studio)

Table 6 (parts 1 and 2) represents the VAR model estimation results. The first column represents the estimation results for REC. CO_2 emissions (CO_2.L1 -0.434650**), (CO_2.L2 -0.700241***) both lags negatively impact REC. If the CO_2 emissions increase, there must be a significant decrease in REC. Similarly, many studies, such as Bilgili et al. (2016) found that REC has significant and negative impacts on CO_2 emissions, however Nguyen & Kakinaka (2019), found that REC significantly impacts CO_2 positively and negatively in terms of low-and high-income countries respectively. This result also supports the result of quadratic regression analysis, which is presented in Table 5 column (6). Interestingly, GDP per capita is also positive and negative for primary and squared terms with both lags, respectively, but not significant as the result of regression analysis in Table 5.

The second column of Table 6 presents estimation results for CO_2 emissions. Here we can see that PGDP is statistically significant, with both lags in primary and squared terms of it. Gross domestic product per capita lag 1 primarily shows (PGDP.L1 -5.279626**) negatively significance toward CO_2 emission, while the squared term ($PDGP^2$.L1 0.284026***) is positively significant for its increase. This is also the case for the simultaneous equation (5) presented in Table 5. The Environmental Kuznets curve (EKC) hypothesis is not supported by our findings of statistical significance in term of PGDP and CO_2 relationship here, so our selected European Union countries do not have any properties to support the Environmental Kuznets curve (EKC) hypothesis during our study period (2010-2019). Begum et al. (2015) refers that their study found the EKC hypothesis invalid for their selected country during the study period.

In Table 6, the third column displays the estimated outcomes for GINV. In contrast with the regression findings, the VAR analysis indicates that not all the core variables are significant for GINV. Carbon emissions have (CO_2.L1 -1.16103*) negative and positive (CO_2 .L2 2.66644***) impacts on green investments. This could be due to the fact that, in the short run, an increase in carbon emissions necessitates a policy demand for more environmentally friendly infrastructure, and this increases the need for green investments. Renewable energy consumption is also positively significant for green investment.

The last column presents Per Capita Gross Domestic Product (PGDP) estimation results. Carbon emissions show statistically significant (CO_2.L1 -0.966578***) negative and positive (CO_2.L2 0.950189***) impacts on PGDP. However, in Table 5, green investment has a significant impact On PGDP, where lag1 is positive (GINV.L1 0.451133***), and lag 2 is negative (GINV.L2 -0.710451***). Conversely, the squared term of the green investment is significant for both lag 1 and 2. Lag 1 has (GINV2.L1 -0.029870***) negative and lag 2 has positive (GINV.L2 0.049851***) impact on the economic growth variable. Regarding regression analysis in Table 5, we also see a link between GINV and PGDP. The study of Lyeonov et al. (2019) on European Union countries during the years 2008-2016 found that green investment can provoke the growth of PGDP, also, there is a link between renewable energy and greenhouse gas emissions with the gross domestic product per capita.

5.4.1 VAR model diagnosis

A model with fewer assumption violations and better diagnostic test results can be deemed more dependable. To determine the reliability of the VAR model, it's essential to conduct diagnostic tests that evaluate its assumptions and detect any statistical issues like heteroscedasticity, autocorrelation, or the normality of residuals.

Diagnosis test	Chi-squared and P-value	Decision
Heteroscedasticity ARCH (multivariate)	Chi-squared 3870 p-value 1	➢ No heteroscedasticity
Serial Correlation Portmanteau Test(asymptotic)	Chi-squared 1468.5 p-value < 2.2e-16	➢ Serial correlation exists
Normal Distribution of the Residuals Skewness (multivariate)	Chi-squared 20.886 p-value 0.01317	➢ The distribution is approximately symmetric.
Kurtosis (multivariate)	Chi-squared 24.344 p-value 0.00379	➢ approximate normal

Table 8 - Diagnostics test results on the VAR model

5.5 Granger causality test and discussion:

The Granger causality test we have used to investigate the causality among our selected variables for this thesis. Table 7 presents all estimated results of the Granger causality test. We have found unidirectional, bidirectional, and no functional relationship between the concerned variables.

Hypothesis (Y ~ X)	Pr(>F)	Decision on X Granger causes Y(statistically significant)
PGDP~CO_2	6.183e-06 ***	Bidirectional causality (Statistically significant)
PGDP~REC	0.1785	No functional causality (Statistically insignificant)
PGDP~GINV	0.4776	No functional causality (Statistically insignificant)
PGDP~$GINV^2$	0.3848	No functional causality (Statistically insignificant)
PGDP~ETAX	0.0805.	Unidirectionally causality (Statistically significant)
PGDP~GEDU	0.9484	No functional causality (Statistically insignificant)
PGDP~UP	4.223e-15 ***	(Statistically significant)
CO_2~PGDP	0.07202.	Bidirectional causality (Statistically significant)
CO_2~$PGDP^2$	0.09139.	(Statistically significant)
CO_2~REC	0.006853 **	Bidirectional causality (Statistically significant)
CO_2~GINV	1.683e-12 ***	Unidirectional causality (Statistically significant)
CO_2 ~$GINV^2$	3.24e-11 ***	(Statistically significant)

CO_2~ETAX	2.2e-16 ***	Unidirectional causality (Statistically significant)
CO_2~GEDU	0.7315	No functional causality (Statistically insignificant)
CO_2~UP	0.8261	No functional causality (Statistically insignificant)
REC~PGDP	4.852e-09***	Unidirectional causality (Statistically significant)
REC~$PGDP^2$	6.306e-09***	(Statistically significant)
REC~ CO_2	0.03346*	Bidirectional causality (Statistically significant)
REC~GINV	4.486e-07***	Bidirectional causality (Statistically significant)
REC~$GINV^2$	1.149e-05***	(Statistically significant)
REC~ETAX	1.887e-09***	(Statistically significant)
REC~GEDU	0.07628.	(Statistically significant)
REC~UP	0.0001834***	(Statistically significant)
GINV~PGDP	0.002652**	Unidirectional causality (Statistically significant)
GINV~$PGDP^2$	0.003315**	(Statistically significant)
GINV~ CO_2	0.5128	No functional causality (Statistically insignificant)
GINV~REC	0.06538.	Bidirectional causality (Statistically significant)
GINV~ETAX	1.166e-07***	(Statistically significant)
GINV~GEDU	0.4654	No functional causality

		(Statistically insignificant)
GINV~UP	0.0001335***	(Statistically significant)

Table 9 - Granger causality test results

Signifiance codes : 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 (model estimated by ‘R’ studio)

Finally, we conducted a Granger causality test to determine the statistical significance of forecasting future values for all the selected variables. As presented in Table 7, the results reveal bidirectional causality between PGDP and CO_2 emissions. Here CO_2 emissions provide statistically significant information to predict the future values of economic growth of our selected countries and vice versa. However, Jobert et al. (2010) studied the convergence of per capita CO_2 emissions in the EU for the time period 1971 to 2006 has stated that the future value of CO_2 is impacted by the value of PGDP. Another bidirectional causality was found between REC and CO_2 emissions, which we also found in our other models’ analysis results. Radmehr et al. (2021), in their study on European Union between the years 1995 to 2014, found unidirectional causality between REC and CO_2 emission. We have found that both variables have statistically significant level of causality. Interestingly, we found bidirectional causality between REC and GINV. One of the economic benefits of green investing is the improvement of social, economic, and environmental factors, ultimately leading to an increase in REC. GINV mainly focuses on funding green energy projects that support using renewable energy in the economy. However, GINV has unidirectional Granger causality with carbon emissions in this model. Granger test results show that GINV has the highest statistical significance level (1.683e-12 ***) in predicting the future value of CO_2 emissions. On the other hand, CO_2 emissions has no significant impact (0.5128) on predicting the future value of GINV for our selected countries during the study time duration. However, PGDP shows statistical significance (0.002652**), and unidirectionally granger causes GINV. Lyeonov et al. (2019) studied the European Union country’s GINV impact on sustainable development during 2008-2016 and found a significant link between GINV and PGDP. In our analysis, the economic growth variable, ‘PGDP’, significantly influences predicting the future ‘GINV’ of the concerned European Union countries.

CHAPTER 6: CONCLUSION, POLICY RECOMMENDATIONS AND LIMITATIONS

6.1 Conclusion and Policy Recommendations

The rising temperatures, increasing sea levels, and many other environmental degradations negatively affect productivity. Environmental degradation has a significant negative impact on the world's economy. It is high time to reduce humanly produced pollution and promotes environmentally friendly innovation to achieve sustainable economic growth.

The empirical model's analysis results support that green investment has statistically significant influences on renewable energy consumption and economic growth of the selected EU countries. This finding shows the importance of renewable energy in reducing carbon emissions and achieving sustainable economic growth for the selected EU countries. Our findings of quadratic regression and the VAR model indicate that carbon emissions have a significant and negative dynamic with renewable energy consumption. Our results indicate that if carbon emissions increase, renewable energy consumption will decrease. This result emphasizes prioritizing clean energy consumption to achieve the United Nations' sustainable development goals. Governments must establish policies that promote the use of affordable renewable energy.

Further, the study results show that renewable energy consumption positively affects economic growth in quadratic regression and the VAR model. This result refers to increased renewable energy consumption, which will also increase economic growth. The government, policymakers, and industry should promote research and development and expand investment into these renewable energy technologies. There should be a motive for an evidence-based policy to subsidize and encourage the establishment of more new renewable energy industries. The analysis also shows that gross domestic product per capita has a statistically significant relation with carbon emission and green investment in all the empirical models. It proves that a causal links exists between them for the selected EU countries in our study. Our research findings demonstrate that carbon emissions has bidirectional relationships exist between renewable energy consumption, and economic growth in the selected ten EU countries.

Moreover, green investment and renewable energy consumption also have bidirectional causality. On the other hand, the empirical results also confirm that economic growth has an unidirectional causality toward green investment and renewable energy consumption. The energy sector is a crucial industry that directly impacts a country’s economy. However, it is also a major source of pollution. The findings refer that to lower carbon emissions, the government in selected countries should develop policies that promote investing in renewable energy sources and encouraging more renewable energy consumption.

Suggesting these policy directions cannot be seen to be enough; frequent monitoring and evaluation of the progress expected from increased investment into green technologies and renewable energy sources should be a priority. In addition to internal policies, there should be renewed commitment and cooperation with international organizations and the road map to reaching sustainable economic development. These activities should be backed by active sensitization and increasing awareness about the dangers of climate change and environmental degradation. Moreover, we suggest more trade openness between countries regarding sustainable green technologies. Policymakers should reconsider policies to increase environmental protection taxes for more revenue to invest in the environmental protection industry and renewable energy industry to expedite decarbonization from production outcomes of the non-renewable energy industry.

6.2 Limitations of the Study

One of the study's limitations is that we extracted the data from only ten European countries because of the data availability of the considered variables. Future researchers may include more countries and can conduct a country comparison considering the economic growth rate to determine how these causal relationships hold in developing and developed nations. There will also be room for increasing the study period and inspecting the monthly or quarterly data to ensure increased robustness of the analysis.

Additionally, we have used the linear and quadratic regression analysis, the VAR model, and Granger causality tests to estimate and investigate the causal relationships among the specified variables of our study (green investment, carbon emissions, renewable energy consumption, and economic growth). Future researchers may enhance and incorporate different analytical models in their study. Models such as ARDL and NARDL that allow non-linear analysis can be adopted. In the same way, further research can be performed by including more control variables or indicators in these models. For example, foreign direct investment, urbanization, technological improvement, financial innovation, and global value chain, which according to some literature, also might have an impact on reducing carbon emissions, increasing renewable energy consumption, promoting green investment, and accelerating economic growth can be added to this analysis.

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