EXPLORING THE NEXUS OF ENERGY CONSUMPTION, NATURAL RESOURCES, HUMAN DEVELOPMENT, RENEWABLE ENERGY AND ECOLOGICAL FOOTPRINT: A CASE STUDY OF EUROPEAN UNION COUNTRIES

BY

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DECLARATION

We hereby declare that:

(1) This undergraduate research project is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

(2) No portion of this research project has been submitted in support of any application for any other degree or qualification of this or any other university, or other institutes of learning.

(3) Equal contribution has been made by each group member in completing the research project.

(4) The word count of this research report is 9877.

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CHAPTER 1: RESEARCH OVERVIEW

1.0 Introduction

The Ecological Footprint is a crucial metric for measuring humanity's contribution to the planet, indicating human activities and resource utilization relative to the Earth's biocapacity. The research manifests across Europe as a multifaceted indicator entrenched in energy consumption patterns, natural resource utilization, human development indicators, and the transition to renewable energy sources. High-income countries tend to have high per capita Ecological Footprints given their high consumption levels, while low-income countries struggle to satisfy their basic needs. Europe is under significant pressure owing to its large dependence on fossil fuels, resulting in a vast carbon footprint and ecological deficit. However, Europe is dedicated to serving as a role model for other regions by implementing the European Green Deal to transform the continent into a resource-efficient, low-carbon society. Furthermore, the policy reflects a trade-off between the ecological footprint and human well-being to create sustainable development and governance. As such, it is worth questioning whether the move to renewable energy sources will enable Europe to reduce its ecological footprint and contribute to sustainable environmental conservation.

1.1 Research Background

The Ecological Footprint measures the number of human activities on Earth. The amount is defined as the quantity of biologically productive land and water that must be used to produce what is consumed and absorb waste generated by a person, community, product, or population using currently prevailing technology resource management practices (*Ecological Footprint*, n.d.-a). This figure is given in global hectares (gha), which are standard units of measurement taking into account the average productivity of all biologically productive areas on Earth in a given year (*What Is an Ecological Footprint?*, n.d.).

The Ecological Footprint encompasses various components, including the area needed for growing crops, grazing livestock, harvesting timber, accommodating infrastructure, and fishing. It also includes the forest area required to absorb carbon dioxide emissions that are not absorbed by the ocean, particularly those emissions resulting from the burning of fossil fuels (*Ecological Footprint*, n.d.-b). To measure whether the world can support continuous development and whether people are living within the natural resources sustainable level The concept of the Ecological Footprint has been devised. It's a method of calculating how much impact humans have on natural resources and the planet's ability to replace them that also indicates differences in material wealth between rich and poor countries (Nautiyal & Goel, 2021). Intuitively, high-income countries have a higher per capita Ecological Footprint due to greater levels of consumption and waste. On the contrary, low-income countries often struggle to meet basic needs (*Goal 12: Ensure Sustainable Consumption and Production Patterns*, n.d.).

Ecological Footprint can be calculated at various scales, from a single person to the entire global population. It is used by scientists, businesses and organizations in specific situations such as for the World Wildlife Fund to monitor ecological resource use in contemporary society. The Global Footprint Network is one of the key organizations establishing that Ecological Footprint can be used as an indicator of ecological sustainability. It provides an agreed standard for measurement and policies to manage Earth's ecological resources within its bio-capacity constraints also originate with them (*Ecological Footprint*, n.d.-a).

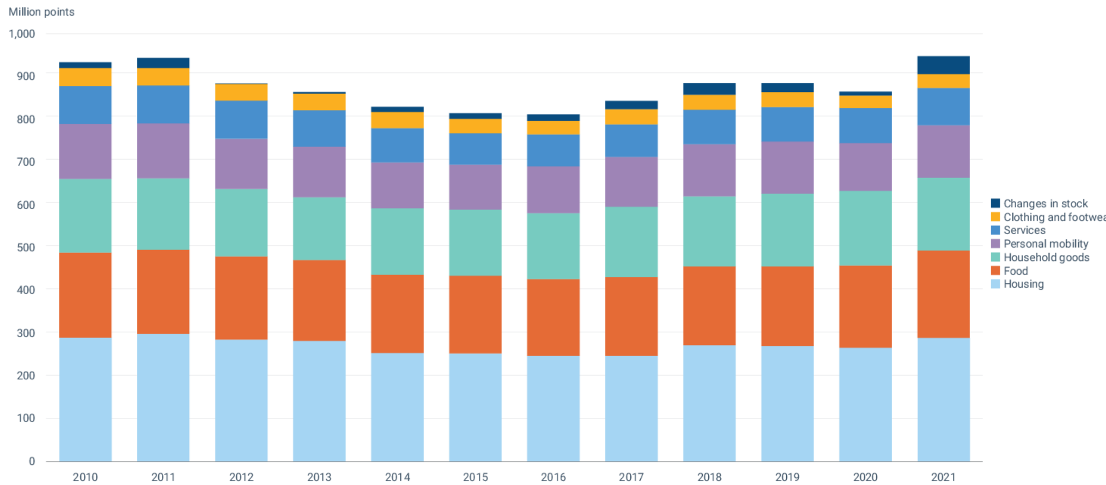
There are several reasons why the ecological footprint is crucial to a country. First of all, the ecological footprint will tell us whether a country lives within the biocapacities of its territory or not. This helps determine sustainability for consumption patterns and resources used in countries (Rudolph & Figge, 2017). Second, a country with a high ecological footprint may run into economic hazards such as resource scarcity, increasing costs for importing resources, and potential strife over resource access. Discussing and managing ecological footprints can help lower these risks (Rees, 2006). Thirdly, a component of the ecological footprint is the carbon footprint, which measures how many greenhouse gases people is generating Click or tap here to enter text.. Lowering and managing the ecological footprint can help to mitigate climate change by decreasing carbon emissions.

European ecological footprint currently is due to a combination of factors, including globalization, consumption patterns and policy initiatives for sustainability. The land absorbs resources, but where the increasing masses of consumer goods are purchased, both energy and materials consumption soar dramatically. Not only do European countries have huge ecological deficits, but they also face the risk of falling into deep environmental poverty. An analysis organizes global precursors into a comprehensive package. It states that the impact on the ecological footprint of economic and social globalization is far greater than the impact on the ecological footprint of political globalization. The conclusion of this is that they contribute significant content toward creating a cleaner world. (Karimli et al., 2024).

The World Wildlife Fund (WWF) disclosed that Europe remains in an ecological overshoot, pointing out that its carbon footprint makes up nearly 50% of its total ecological footprint. This is mainly due to the burning of fossil fuels such as coal, oil, and natural gas (*EU Continues to Run an Ecological Deficit, Says New Living Planet Report -Tackling CO2 Emissions Will Significantly Reduce Its Ecological Footprint*, 2014). The extraction and usage of fossil fuels are quite impactful on Europe's ecological footprint, it contributes to a significant portion of the world's greenhouse gas emissions, as well as water stress, biodiversity loss, and ecosystem collapse (Mushafiq & Prusak, 2023). The European Union's policies, such as the European Green Deal (EGD), aim to raise economic performance while reducing the strain on natural resources and achieving a resource-efficient and productive economy with zero net emissions of greenhouse gases by 2050 (Vela Almeida et al., 2023). A great stepping stone is that the environmental impacts of resource extraction and consumption remain a big challenge for such achievement.

The result of the ecological deficit means that European consumption of natural resources is greater than the biocapacity available within its boundaries, leading to environmental breakdown and reliance on imports for environmental goods and services (Vandermaesen et al., 2019). Furthermore, food consumption is a key driver of the ecological footprint in the EU-27 region. Even though the average per capita footprint of this region fell by 20% between 2004 and 2014, it still lives beyond its means; food consumption makes up most share of total ecological input per year (Galli et al., 2023). 30% of the EU's ecological footprint is attributed to food consumption (Sanyé-Mengual et al., 2023). This urges a need of sustainable agricultural practices and policy interventions are needed to address European food production, consumption, wastage and trade patterns. The European Environment Agency (EEA) discusses the EU's consumption footprint and the challenges in reducing it by 2030. From Figure 1.1.1, it shows almost no changes in terms of EU’s consumption footprint in almost a decades. It suggests strategies such as shifting to less environmentally harmful goods and services, consuming less, and scaling up the eco-design of new products. Despite some countries showing a decrease in their consumption footprint, the overall trend indicates a continuous increase, making it a serious challenge to achieve sustainability goals (*Consumption Footprint: Top-down Approach*, 2024).

Figure 1.1.1: Weighted Impacts of EU consumption

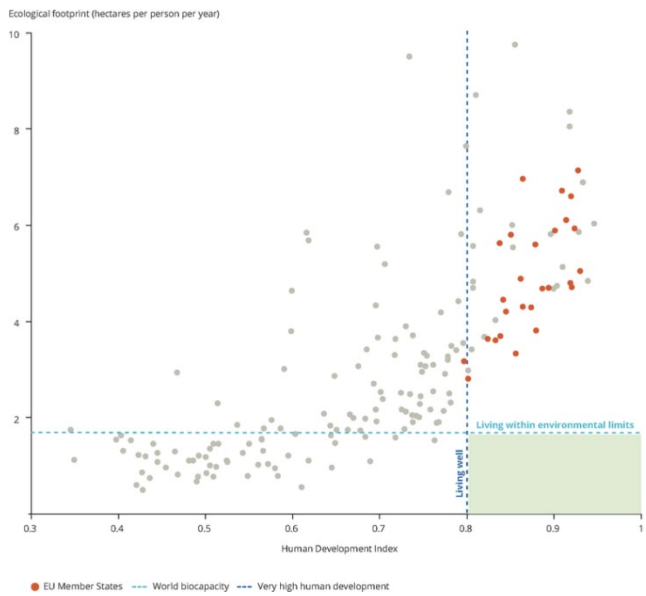


Sources: Consumption Footprint: Top-down Approach (2024)

Human development has been correlated with environmental implications where the ecological footprint has been considered. Given that more resources such as energy, water, and raw materials are consumed as economies continue to expand, the ecological footprint increases (Zafar et al., 2019). Moreover, the activities in expanding industrial and infrastructural development in Europe resulted in resource consumption and carbon emissions that accounted for the continent's ecological footprint (Sarkodie et al., 2020). Consumptive behaviors linked to high living standards like consumer goods, transportation, and services intensify the ecological footprint in Europe.

The most developed nations, such as European countries, perhaps most painfully demonstrate a combination of several causes, which are the high levels of foreign direct investment, technological leadership, and economic growth. However, their environmental costs are perhaps the most obvious: in the case of high GDP per capita, life expectancy, health expenditure, and investment into research, the significant ecological footprints of the mentioned countries are truly striking. From Figure 1.1.2, it shows a high correlation between Human Development and Ecological Footprint in the EU. Despite their advanced human development indices, they usually experience at the same time critically large ecological deficits, where the potential of the ecosphere available for use becomes scarce to address all the needs (Ghita et al., 2018).

Figure 1.1.2: Correlation between Ecological Footprint and Human Development Index (HDI) in Europe



Sources: Correlation between Ecological Footprint and Human Development Index (2019)

It has been revealed that there is a robust trade-off relationship between ecological footprint and human well-being across European nations. Both the quality of human well-being and the ecological footprint tend to increase as the other reduces. However, with proper sustainable education, this can reduce this trade-off and maximize them to jointly ensure environmental and human development (Nathaniel, 2021). This indicates a combined pattern as the relationship in the statement above, similar to the Environmental Kuznets Curve (EKC) pattern. At low levels of development, the relationship tends to be high but declines after several high levels of development (*Correlation between Ecological Footprint and Human Development Index*, 2019). This phenomenon explains the need to have education approaches and sustainable practices to be able to navigate between development and conservation.

In 2022, renewable energy sources accounted for 22.5% of final energy consumption in the European Union. Solid biomass made up 40% of the total renewable energy supply, followed by wind (15%), hydropower (10%), and liquid biofuels (7%). The renewable share more than doubled between 2005 and 2022 due to dedicated policies and appropriate support schemes (*Share of Energy Consumption from Renewable Sources in Europe*, 2024). Renewable energy provides stuff in the long run decreases the ecological footprint because it has a long-term negative impact on the ecological footprint, and a study of the effect of renewable energy consumption on the ecological footprint shows its contribution to decreasing it is 1.34% on average (Sherif et al., 2022).

Renewable energy consumption results in an improvement in environmental quality in Central European countries, with digitalization and financial development functioning as mediators. The replacement of coal with renewables and nuclear energy resulted in a reduction in CO2 emissions in Europe (Jóźwik et al., 2023). Whereas in Western European countries, emissions grew as the growth of the countries depended on energy-intensive activities; on the other hand, renewable energy consumption limited emissions by reducing energy intensity (Mahmood et al., 2024). In the year 2018, the European Union has announced to set ambitious targets of increasing the share of renewable energy to 32% by 2030 (Ntanos et al., 2018).

For a few reasons, researching the factors that affect the ecological footprint in Europe and its adoption of renewable energies is critical for many thinkers. Firstly, draw European country' ecological deficits as the most ecologically sensitive, from this perspective understanding the link between energy consumption and environmental destruction is essential for fashioning effective public policies in pursuit of sustainability goals. Secondly, moving towards renewable energy resources provides a chance to reduce the ecological footprint. By cutting back on fossil fuels and lowering greenhouse gas emissions, this process reduces environmental pressure and increases its fragility. Reviewing the impact of that process on environmental quality and natural resources may drive us to abandon current use or policy perspectives. After all, further studies of the relationship between ecological footprint and human wellbeing can help find ways to achieve a balanced growth that will maintain both well-being and the environment for generations present future. By addressing these research questions, we can move towards a more sustainable and resilient future that is not only Europe's but the world's.

1.2 Problem Statement

1.2.1 Energy Consumption

Energy consumption, particularly from fossil fuels, is a significant driver of the ecological footprint. Burning fossil fuels releases greenhouse gases contributing to climate change, and it often involves resource-intensive extraction processes. Therefore, higher energy consumption tends to correlate with a larger ecological footprint. However, the type of energy consumed matters. Renewable energy sources like wind, solar, and hydropower have a lower ecological footprint compared to fossil fuels. So, transitioning to renewable energy can potentially reduce the ecological footprint associated with energy consumption.

1.2.2 Natural Resources

Natural resources are directly linked to the ecological footprint as they are the basis for human activities. The extraction of natural resources for various purposes such as agriculture, manufacturing, and construction contributes to ecological degradation. Deforestation, overfishing, and depletion of water resources are examples of how natural resource exploitation impacts the ecological footprint. Sustainable management of natural resources is essential to mitigate this impact and ensure the ecological footprint remains within planetary boundaries.

1.2.3 Human Development

Human development encompasses various socio-economic indicators like GDP per capita, education, healthcare, and living standards. Higher levels of human development are often associated with increased consumption and resource utilization, leading to a larger ecological footprint. However, there's also evidence suggesting that strong institutions and sustainable practices can decouple human development from ecological footprint growth. Therefore, fostering sustainable development pathways is crucial to managing the ecological footprint effectively.

1.2.4 Renewable Energy

As mentioned earlier, renewable energy sources have the potential to reduce the ecological footprint, especially when they replace fossil fuels. By generating energy from sources like wind, solar, and hydro, countries can decrease their reliance on fossil fuels, thereby reducing carbon emissions and environmental degradation associated with energy production. The expansion of renewable energy infrastructure is a key strategy for mitigating the ecological footprint and transitioning towards a more sustainable energy system.

1.3 Research Questions

1. What is the relationship between ecological footprint, energy consumption, usage of natural resources, human development and renewable energy transition in European countries?

2. What role does human development play in mitigating the trade-off between ecological footprint and human well-being?

3. To what extent does the transition toward renewable energy contribute to reducing the ecological footprint in Europe?

1.4 Research Objective

1. To analyze the correlation between ecological footprint, energy consumption, usage of natural resources, human development, and renewable energy transition in European nations.

2. To investigate the role of human development in moderating ecological footprint and human well-being.

3. To assess the effectiveness of renewable energy transition in mitigating the ecological footprint in Europe.

1.5 Significance of the Study

The importance of the conducted research lies in the possibility of understanding the various factors within the structure and the relationship between energy consumption, natural resource consumption, human development and renewable energy transition in European Union countries. As the ecological footprint depends upon many factors, and humankind uses all possible measures for human development besides modern resources, the outcomes obtained through this study will help develop a proper strategy for balancing economic growth and ecological concerns in Europe.

1.6 Conclusion

The ecological footprint is a critical framework to measure and analyze the interrelation of energy consumption, natural resources consumption, human development, and the transition to renewable energy throughout Europe. As presented above, the assessment and research findings will analyze variables with sustainability motives. One of the key drivers of the expansion of the ecological footprint is energy consumption, particularly the extensive use of fossil fuels. Thus, the transition toward renewable sources is currently one of the most pressing issues and is gradually being adopted by the countries. Similarly, the utilization of resources and human development play an equally important role in expanding the ecological footprint as they depend on unsustainable development and management practices. Lastly, as demonstrated above, the transition to renewable energy provides a feasible method to mitigate EF growth. Therefore, the research intends to study these variables to create feasible techniques to balance industry development and environmental conservation and build the future of the European continent on sustainability and resilience.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

We have understood that ecological footprint is an important topic that is worth researching and is influenced by several factors as stated in the last chapter. In this chapter, we conduct an extensive literature review to examine existing research papers that explored the determinants of ecological footprint in different parts of the world. The purpose of the literature review will be to develop a deeper understanding of how energy consumption, natural resource utilization, human development, renewable energy transition, and ecological footprint interact with each other. We will also seek economic theories that will help understand the domains of the linkages between the variables. These theories will establish the foundation for our theoretical framework and research hypotheses. Combining empirical evidence with theoretical approach, we will develop a sound theoretical framework that explains the linkages between variables and the direction of our research. This chapter will form the cornerstone of our research to provide a solid theoretical and empirical basis for the subsequent data analysis and findings.

2.1 Review of the Literature

2.1.1 Ecological Footprint and Energy Consumption

Ritu & Kaur (2024) examined the energy consumption dynamics conducted in India with the ARDL bound test. According to the results, there was a positive and significant effect of non-renewable energy consumption on the ecological footprint. These results suggested the need for sustainable sources of energy generation to curb the environmental impact of natural depletion. Thus, reducing the use of fossil fuels might not be sufficient in addressing the ecological degradation that occurs with time. A paper in Indonesia continued the investigation of non-renewable energy consumption and environmental degradation based on the VECM framework to analyze the long-term relationship between non-renewable energy consumption and energy degradation. The findings show a positive association. The research urges interventionist solutions that help reduce the past accumulated damage. (Kurniawan et al., 2023). Hussain & Mahmood (2023) conducted a robust NARDL on the linkage between energy consumption and environment quality in Pakistan and also found a positive and significant impact of fossil fuel energy consumption on ecological deterioration. The study identified this impact majorly due to the significant share of fossil fuel in the energy production mix and thus the need to reduce this dependence to improve the environmental quality. Additionally, one recent study carried out on the causal effect of primary energy consumption of fossil fuels and environmental sustainability in Indian countries found that NARDL results provide alternate confirmation of the deleterious impact on fossil fuel utilization. This includes the emission of greenhouse gases, the high possibility of global warming and reduction of biodiversity, and calling for policy attention towards cleaner technologies to minimize environmental degradation. (Khan et al., 2023). Lastly, Ibrahiem & Hanafy (2020) conducted a study in Egypt using the FMOLS to investigate the relationships between fossil fuel use and environmental degradation. The authors also find a positive and significant relationship, confirming Egypt's position in Africa as a leading consumer of gas and oil. Similar to the other articles discussed earlier, this study reinforces the importance of renewable energy efforts, considering that fossil fuel use has significant negative environmental effects.

2.1.2 Ecological Footprint and Natural Resources Consumption

The research was made by a comprehensive study through the usage of the Generalized Linear Model in investigating the relationship between the source and index of natural resource depletion of the ecological footprint of China India and the United States the result of the paper showed a clear strong direct correlation. The research concludes that if appropriate action is not taken, the environment will be a victim of environmental disaster. (He et al., 2024). Contrastingly, Qing et al. (2024) employed the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group methodologies to explore the impact of total natural resource rent on ecological footprint in six South

Asian countries. The result of the study reveals a significant positive relationship, including key indicators such as groundwater depletion and deforestation, which need to be conserved to reduce environmental degradation. Conservation is mandatory to mitigate resource scarcity, contamination, and extinction due to pollution. In a different context, Uzar (2024) used the AMG approach to assess the effect of renewable natural resources on environmental pressure: in E7 countries. The results indicated that there was a statistically significant negative correlation. As a result, the mere existence of renewable natural resources could mitigate some of the ecological footprints due to a decrease in fossil dependence. On the other hand, a study paper used the ARCH methodology to assess the relationship between total natural resource rent and the ecological footprint in the United States. Their results showed there was a significant positive correlation. This implies that the natural resource burden plays a substantial role in the development of environmental outcomes. Thus, employing efficient natural management strategies is critical in reducing ecological deterioration in the United States (Kang et al., 2023). Lastly, Xia & Liu (2024) used the Nonlinear Method of Moments Quantile Regression (MMQR) to investigate the effect of total rent revenue on the ecological footprint in G7 countries and also obtained a positive significant correlation. The unsustainable nature of natural resource extraction and its use in developed economies. The need to transition to sustainable resource management procedures to reduce ecological deprivation that arises from the inefficient use of resources.

2.1.3 Ecological Footprint and Human Development

A study utilizing the FMOLS to examine how the Human Development Index impacts the ecological footprint in G7 countries. The results indicated a negative significant relationship. According to the research, the social and income aspects of human development may drive sustainable development, thereby reducing the ecological footprint. In this regard, comprehensive human and environmentally oriented answers are essential to reducing the ecological footprint (Balsalobre-Lorente et al., 2024). Similarly, Pata et al. (2021) employed the Augmented Mean Group estimator to test the connection between HDI and ecological footprint in ten countries with the highest EF. They also proved a significant negative relationship. People with higher education, capital, and health are extroverts. Hence, this investigation illustrates the possibility of human improvement in developing environmental responsibility and longevity. In a different context, Sun et al. (2023) applied the CS-ARDL method to analyze the effects of the Human Capital Index on the ecological footprint in NEXT11 countries. Overall, the study's findings indicate a statistically significant negative relationship, meaning that more human capital results in more environmental cognition and pro-environmental conduct. Education plays a significant role in empowering citizens to be proactive in environmental conservation. Contrastingly, a paper examined the impact of education variables on the ecological footprint using Augmented Mean Group across E-7 and G-7 countries. They found distinctive impacts: the education system in E7 countries has led to the increase of fossil fuel energy and has no significant focus on the provision of environmental science education or awareness, while that of G-7 countries influences citizens to be pro-environmental. Therefore, context-based education reforms to foster environmental education and consciousness are needed. (Huang et al., 2022). Lastly, Mbiankeu Nguea & Hervé Kaffo Fotio (2024) conducted a study implementing Panel Quantile Regression to investigate the association between HDI and ecological footprint in 31 African countries. They established a significant negative correlation, implying that educated people are enabled to engage in advocacy for environmental conservation. Hence, according to this source, human development has the potential for transformation and motivation to initiate a favorable redistribution of behavior consumption.

2.1.4 Ecological Footprint and Renewable Energy

Padhan & Bhat (2023) conducted a study using the Driscoll-Kray standard error panel regression to assess the impact of renewable energy consumption on the ecological footprint of BRICS and NEXT-11 countries. The academicians found a negative significant association and indicated that clean and green foreign investments investment may help to decrease emissions and encourage eco-friendly practices in developing nations. To achieve sustainable development targets, the state must support renewable energy proposals. Similarly, Kurniawan et al. (2023) utilized the VECM framework to assess renewable energy consumption and ecological footprint in Indonesia. The results of the study revealed a long-run negative and significant relationship. They concluded that Indonesia should shift to clean energy to minimize greenhouse gas emissions. Additionally, it is important to ensure resources are optimally utilized and invested in renewable energy to promote environment-friendly industrial activities. Meanwhile, another study on renewable energy consumption and ecological footprint in Germany was done using the ARDL methodology. The result also indicates a negative and significant in the long run and short run. The role of renewable energy such as hydro, solar, wind, and geothermal energies in reducing ecological footprint was highlighted. The study concluded that it is critical to save energy and utilize renewable energy to enhance the environment. (Ali & Kirikkaleli, 2024). Contrastingly, Vardar et al. (2023) conducted a comprehensive analysis across 47 developing countries utilizing FMOLS, DOLS, and PMG-ARDL methods to assess the impact of renewable energy consumption on ecological footprint. The results showed a positive impact. The effectiveness of support for renewable energy projects and the provision of green financial assistance is sufficient for increasing environmental quality and sustainable development goals. Lastly, a research paper analyzed the effect of renewable energy consumption on the ecological footprint in the United Arab Emirates applying the ARDL bound test and DOLS. The results are statistically significant and negative both in the short and long run. A higher degree of elasticity of renewable energy into the promotion of environmental sustainability compared to nonrenewable energy was identified. The papers supported the increase in the ecological footprint and sustainable development by policymakers based on the positive effect of renewable energy (Arnaut & Dada, 2023).

2.2 Economic Theories

2.2.1 Environmental Kuznets Curves

The Environmental Kuznets Curve theory was introduced by Simon Kuznets in 1955 (Kuznets, 1955). This theory explains that there is an inverted U-shaped relationship between economic development, which is then based on GDP per capita, and environmental degradation. In the short run, as the economy grows, more environmental degradation is experienced because countries become more industrialized and consume more resources. In the long run, however, after a certain level of economic progress is obtained, countries establish a higher priority for environmental measures which causes a diminishing value of environmental degradation. In our study, level of the human development, which will be represented as economic growth to observe its effect on the ecological footprint in both the short and long run to check whether this theory can explain the result.

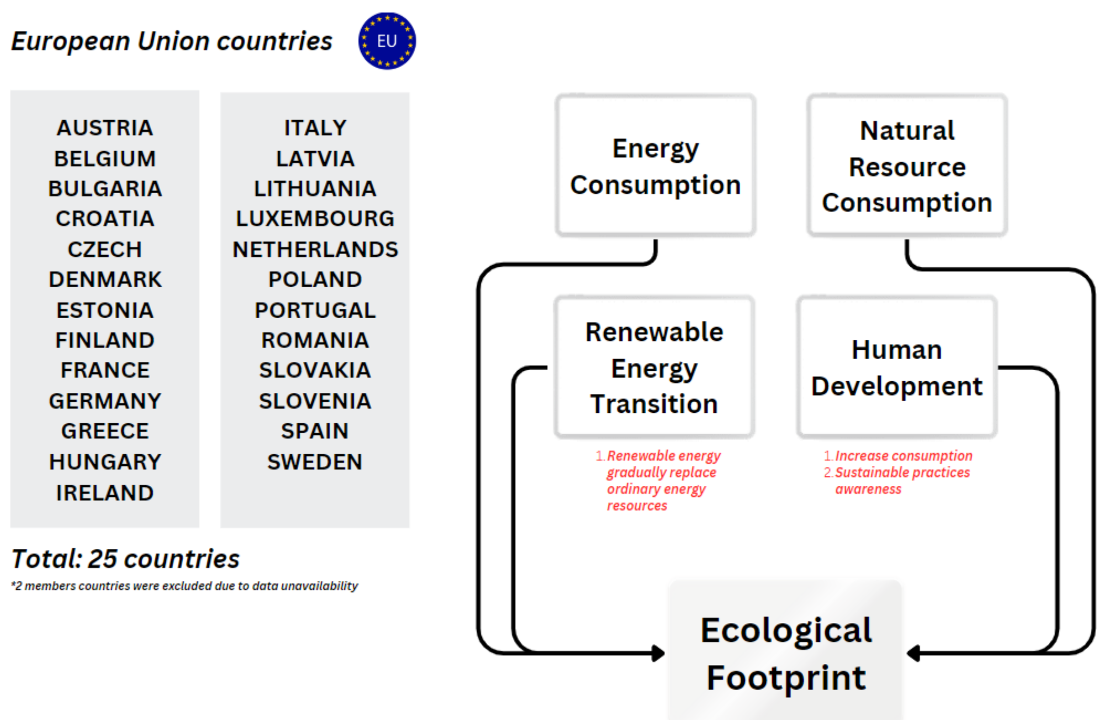
2.2.2 Resource Curse Theory

The resource curse theory often relates to resource-rich economies experiencing lower economic growth compared to resource-scarce economies (Zafar et al., 2019). This phenomenon stems from the negative consequences of resource extraction, which often leads to environmental degradation. Excessive usage of fossil fuels, minerals, and other natural resources contributes to unsustainable exploitation, resulting in ecological footprint and environmental damage. In today's context, Environmental, Social, and Governance (ESG) factors play a crucial role in globalization, meaning that countries with unsustainable practices may receive lesser welfare (Khan et al., 2023). Applying this theory to research is crucial for policymakers to realize the need for effective resource management strategies, such as transitioning to renewable energy sources, to mitigate environmental degradation and foster sustainable development.

2.3 Conceptual Framework

The system depicted in Figure 2.3.1 acts as a road sign that points out our research directions. In the hope of bringing clarity out of complexity, it shows Europe's varied countries in play, the independent variables we are interested in exploring, and their dependent variable. Red fonts are intended for extra emphasis to show the significance of some variables. This framework not only explains what research still lies ahead but by grasping the inter-relatedness of these various aspects makes for a multifaceted understanding that will help shape the methodology and analysis into full sight of the topic.

Figure 2.3.1: Conceptual Framework of Research



2.4 Hypotheses Development

H_{01}: There is no significant relationship between energy consumption and ecological footprint.

H_{A1}: There is significant relationship between energy consumption and ecological footprint.

H_{02}: There is no significant relationship between natural resource consumption and ecological footprint.
H_{A2}: There is significant relationship between natural resource consumption and ecological footprint.

H_{03}: There is no significant relationship between human development and ecological footprint.
H_{A3}: There is significant relationship between human development and ecological footprint.

H_{03}: There is no significant relationship between renewable energy transition and ecological footprint.
H_{A3}: There is significant relationship between renewable energy transition and ecological footprint.

2.5 Conclusion

To conclude, this chapter has provided a critical foundation for the research by reviewing a wide range of literature. The findings of the previous studies have emphasized the importance of the investigation of ecological footprint determinants and highlighted the necessity for further research in this area because in recent years the issue of sustainability has become more and more urgent. Based on these works, we were able to select two macroeconomic theories that could help us in our research. A conceptual framework and hypotheses were designed for this paper, which could help us to analyze and interpret the data in an organized manner. By combining all aspects such as empirical evidence, concepts from academic theorists, and research questions, this chapter laid the foundation for the subsequent analysis of the determinants of ecological footprint.

CHAPTER 3: METHODOLOGY

3.0 Introduction

This chapter is to develop a model strong enough for data analysis while ensuring it adheres to the demands of the research when also striving to obtain the most dependable and efficient estimators. Explicitly determine the parameters and the timing of the analysis, relating them to the research objectives, and to the data dynamics. In this discussion is an extensive analysis of these estimators, comparing their pros and cons in light of the situation of this study. We would rigorously subject these estimators to diagnosis tests and identify those that fit best in the dataset, hence making our analyzed results credible. During our analysis, we will also discuss the habitat of the software for analysis about considerations such as their generalization, how powerful they are, and which estimators they analyze, as well as if they allow for the use of diagnosis tools. Through this study, the prudence to model construction and estimator selection, we get a reliable analysis of the interactions of energy consumption and natural resource consumption, human development, renewable energy transition, and EU ecological footprint.

3.1 Model Specification

To explore the effect of the energy consumption, natural resources consumption, human development and renewable energy transition, the model is specified as below:

$$EF_{it} = con + \theta_{1it}ECON_{it} + \theta_{2it}NR_{it} + \theta_{3it}HDI_{it} + \theta_{4it}SMR_{it} + \upsilon_{it}$$

(1)

where *EF* is the ecological footprint, *ECON* is the energy consumption, *NR* is the natural resources consumption, *HDI* is the Human Development Index, *SMR* is the Share of Modern Renewables. Meanwhile, *con* is the constant, υ is the long-run parameters and υ is the residual terms. Based on the previous literature review, energy consumption tends to increase the ecological footprint following the exploitation of fossil fuels and gases that could result in greenhouse gas emissions and carbon emissions. Besides, the usage of natural resources excessively could result in environmental deterioration and lead to ecological footprint issues as well. Meanwhile, human development shows two different aspects: (1) human development tends to increase ecological footprint as consumption will increase following improvement in the quality of life, (2) human development increases education level that helps create sustainability awareness among people, thus reducing ecological footprint issue. Lastly, the transition toward renewable energy might reduce ecological footprint as non-renewable energy was gradually replaced by energy sources that produce zero emissions and are relatively less harmless to the environment.

3.2 Estimation Approach

This research studies the impact of indicator variables, such as energy consumption, natural resource consumption, human development, and renewable energy transition, on the ecological footprint using panel econometric estimation. Many panel econometric estimation methods are used to explore how different factors influence the ecological footprint. The underlying methods include: first, the Fixed Effects model (FE), an approach that makes estimations by allowing the intercept to vary across entities and controls well for the unobserved time-invariant heterogeneity; it is a convenient approach in cases where unobserved heterogeneity is likely to bear significant correlation with the explanatory variables (Fischer, 2010). If let's say that the entity-specific effect is uncorrelated with the explanatory variables since the Random Effects (RE) model assumes that, then it will be more efficient than FE. Generalized Method of Moments (GMM), a dynamic panel data estimation technique that takes advantage of the possibility of endogeneity by using lagged values of the variables as instruments, is typically appropriate when the dependent variable is likely to be determined by its own lagged values. Whereas the Pooled Mean Group (PMG) Estimation, developed by (Pesaran et al., 1999), allows for the long-run coefficients to be homogeneous across entities but permits short-run coefficients and error variances to differ. This approach is beneficial when studying relationships that are expected to converge in the long run but may exhibit short-run discrepancies due to country-specific factors. Since we are expecting short-run discrepancies when comes to several factors like: 1) The initial introduction of renewable energy might create an ecological footprint as lands will be used to create facilities for production, 2) The rise in Human Development that improve living quality might first increase people's consumption but the condition might change when people start aware of the importance of sustainability practicing. Hence, although energy consumption, natural resource use, human development levels, and renewable energy transition are expected to have similar long-term implications on the ecological footprint, these relationships can appear different in the short run since specific countries have different policies, economic conditions, and technology penetration. Short-term dynamics and error variances can vary across entities, and the PMG framework permits such specifications.

Since PMG approach will be used, the ARDL (p,q,q,q,q) dynamic panel regression for equation (1) is specified as below:

$$EF_{it} = con_i + \sum_{j=1}^{p} \theta_{0i,j} EF_{i,t-j} + \sum_{j=0}^{q} \theta_{1i,j} ECON_{i,t-j} + \sum_{j=0}^{q} \theta_{2i,j} NR_{i,t-j} + \sum_{j=0}^{q} \theta_{3i,j} HDI_{i,t-j} + \sum_{j=0}^{q} \theta_{4i,j} SMR_{i,t-j} + \upsilon_{it}$$

(2)

where p and q refer to the lags of the dependent and respective independent variables. An error correction model is specified through re-parameterized from equation (2), has been specified as follows:

$$\Delta EF_{it} = \pi_i\big(EF_{i,t-1} - con_{1i} - \theta_{1i}ECON_{it} - \theta_{2i}NR_{it} - \theta_{3i}HDI_{it} - \theta_{4i}SMR_{it}\big) + \sum_{j=1}^{p-1} a^*{}_{0i,j}\Delta EF_{i,t-j} + \sum_{j=0}^{q-1} a^*{}_{1i,j}\Delta ECON_{i,t-j} + \sum_{j=0}^{q-1} a^*{}_{2i,j}\Delta NR_{i,t-j} + \sum_{j=0}^{q-1} a^*{}_{3i,j}\Delta HDI_{i,t-j} + \sum_{j=0}^{q-1} a^*{}_{4i,j}\Delta SMR_{i,t-j} + \mu_i + \upsilon_{it} \quad (3)$$

where,

$$\pi_i = -(1 - \sum_{j=1}^{p} a_{0i,j}), con_i = \mu_i, \theta_i = \sum_{j=0}^{q} a_{1i,j,}\theta_{2i} = \sum_{j=0}^{q} a_{2i,j,}\,\theta_{3i} = \sum_{j=0}^{q} a_{3i,j,}\theta_{4i} = \sum_{j=0}^{q} a_{4i,j,}$$

π_i denotes the error correction terms, involving the speed of adjustment of the ecological footprint towards the long-run equilibrium according to equation (3). Moreover, θ's are the long-run coefficient for independent variables, while a's stands for the short-run coefficient. In conclusion, con_i represents the constant, whereas υ_{it} signifies the residual terms.

3.2.1 Lag Length Approach

PMG required the selection of appropriate lag length. The widely used selection criteria in econometrics for Autoregressive Distributed Lag (ARDL) models' lag length is the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Nagawa et al., 2020). AIC and BIC resolved the trade-off between the goodness of the fit and the model complexity, as it ensures researchers not to overfit the data while still incorporating the necessary dynamics (Höge et al., 2018). Both AIC and BIC are derived from the same likelihood function based on the estimated model. They also penalize the model based on the number of parameters presented, suggesting simpler models if they equally interpret many data. However, AIC and BIC differ in the penalization scheme as well as the assumption involved. Researchers have to estimate several ARDL models containing various lag lengths and pick one with the minimum AIC or BIC value. The corresponding lag length for the minimum AIC or BIC informed the choice of lag for capturing variable relationships and maintaining simplicity.

ARDL models with different lag lengths, and their respective AIC and BIC are listed as follows:

Table 3.2.1.1: AIC & BIC comparison between 4 different models

Model	ARDL	AIC	BIC
1	(1,0,0,0,0)	-1360.961	-1334.579
2	(1,1,1,1,1)	-1486.051	-1442.082
3	(1,2,1,1,1)	-1429.881	-1381.983
4	(1,3,1,1,1)	-1354.673	-1302.954

Since Model 2 has the lowest AIC and BIC value, it indicates that this model has the best balance between goodness of fit and model complexity. Hence, it will be chosen for the PMG estimator.

3.2.2 Hausman Test

To test the long-term homogeneity hypothesis, the Hausman test is performed between the Pooled Mean Group (PMG) and Mean Group (MG). According to **Table**, The test statistic is computed and is obtained as 0.6730. Because the test statistic is greater than the critical value at the 5% level of significance, the null hypothesis of homogeneity is rejected, indicating that the PMG coefficient estimates differ significantly from those of the MG. Therefore, the PMG estimator is chosen over the MG estimators because it considers both cross-sectional heterogeneity and potential cointegration. These results reveal that PMG is a more consistent and efficient estimator than MG while studying the associations between energy consumption, natural resource usage, human development, renewable energy transition, and the ecological footprint in European countries, as it imposes no constraint on the regression (Pesaran et al., 1999).

Table 3.2.2.1; Hausman Test to compare PMG and MG models

	Coefficients (b) mg	(B) pmg	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnecon	.7117107	.5705943	.1411163	.2757019
lnnr	.0322012	-.0047264	.0369276	.0778675
lnhdi	2.092697	.5782684	1.514429	1.346841
lnsmr	-.0220347	.0109679	-.0330026	.1473271

b = consistent under Ho and Ha; obtained from xtpmg
B = inconsistent under Ha, efficient under Ho; obtained from xtpmg

Test: Ho: difference in coefficients not systematic

chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 2.34
Prob>chi2 = 0.6730

Sources: Stata 14

3.3 Data Description

The data set incorporates 25 EU member states from 1996 to 2020; however, Cyprus and Malta were not included due to the lack of data availability. The list of countries is shown in Table 3.3.1. Five key variables were obtained, namely ecological footprint, fossil fuel consumption per capita, natural resource rents, human development index, and percentage share of modern renewables in total final energy consumption. Sources to retrieve data include (1) Global Footprint Network (GFN), (2) Our World in Data, (3) World Development Indicators (WDI), (4) United Nations Development Programme (UNDP), (5) International Energy Agency (IEA). The definitions of each variable with their respective data sources were summarized in Table 3.3.2 (See Appendix A). The ecological footprint measures environmental impact considering EU consumption patterns. Fossil fuel consumption per capita reflects non-renewable energy consumption and, subsequently, its contribution to ecological footprint issues. Natural resource rents provide an overview of biocapacity resource utilization, indicating how the particular resources contribute to the ecological footprint. Human development index values show development level and sustainability awareness. Higher human development is related to higher awareness and consumption levels. Percentage share of modern renewables in total final energy consumption to measure the energy transition towards renewable resources. Since a higher percentage indicates the development of energy transition, multiple EU states use modern renewables to mitigate ecological footprint problems. These variables allowed for pinpointing of EU ecological footprint dynamics in the given period.

Table 3.3.1: List of countries

Country
Austria
Belgium
Bulgaria
Croatia
Czech
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxembourg
Netherlands
Poland
Portugal

Romania

Slovakia

Slovenia

Spain

Sweden

Notes: Cyprus and Malta were excluded due to data unavailability

Table 3.3.2: Source of data

Variables	Variable Definition	Data Source
EF	Ecological Footprint (global hectares)	GFN
ECON	Fossil Fuel consumption per capita (KwH in data)	Our World in Data
NR	Natural resources rents (% of GDP)	WDI
HDI	Human Development Index	UNDP
SMR	% Share of modern renewables in total final energy consumption	IEA

Notes: All variables have been transformed into logarithm form

3.4 Research Instrument

The research instrument for this study includes the use of Stata Statistical Analysis software. Stata is a well-known statistical software frequently utilized by researchers in diverse disciplines to assist with data exploration, visualization, reporting, and modeling. The popularity of Stata among researchers may be attributed to the software's straightforwardness and robustness. Stata's robust programming capabilities, for example, enable researchers to quickly produce automated reports and conduct detailed statistical investigations, allowing for quick outcomes while still maintaining accurate and dependable findings. By using Stata, the present research aims to effectively evaluate and interpret collected data on ecological footprint trends in European Union member countries to grasp the variables that affect environmental sustainability over time.

3.5 Research Gap

It is almost certain that higher human development could lead to increased consumption and thus ecological footprint, however, there is a gap in understanding its long-term effects. We utilize a PMG estimator that could help us understand whether high human development could eventually lead to a reduction in ecological footprint through awareness of sustainable practices and societal changes in the long-run.

Second, we utilize the percentage share of modern renewables in total final energy consumption as the variable for renewable energy transition in investigating its impact on ecological footprint. First, non-renewable energy can be seen that it is now gradually replaced with renewable energy in recent years. The obvious evidence is that we can now see the effort of the development of solar power. Second, the development of renewable energy facilities and infrastructure requires the usage of natural resources such as land. Although the transition to renewable energy sources is expected to reduce the ecological footprint, there is still a need to investigate the potential short-term negative environmental impacts. We use PMG estimators in wish to gain insights into the outcomes of renewable energy transition in both the short and long term.

3.6 Conclusion

In conclusion, we have specified the model with a formula that allows us to verify the feasibility of the analysis. The purpose of this research is to establish a framework for analyzing the determinants of ecological footprint to make a significant contribution to understanding its determinants. Moreover, we have implemented a careful approach to the lag length where we determined the suitable ARDL model that maintains the data dynamics. We have also taken the Hausman test, which supports the statement that Pooled Mean Group (PMG) estimators are appropriate to generate valid outcomes. As a result of these methodological foundations and due to the data sources described in the previous sections, the subsequent chapter will focus on the data analysis. The following chapter will generate the desired coefficients in the Stata Statistical Analysis software, which will allow us to explain how the ecological footprint is affected by energy consumption, natural resource utilization, human development, and renewable energy transition indicators in European Union member states. Hence, the comprehensive approach to the study will help identify rigorous outcomes of the models to explore the research question.

CHAPTER 4: DATA ANALYSIS

4.0 Introduction

In the motive to understand the various factors influencing ecological footprint , panel estimation techniques will be implemented. This chapter presents a comprehensive analysis of panel estimations conducted on obtained data from European countries. Through the comparison across different estimators, which are Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE), the most appropriate and robust outcomes will be inspected and reviewed. We would like to analyze and compare both short-run and long-run relationships, this analysis will have numerical evidence of the impacts of energy consumption, natural resource utilization, human development, and renewable energy transitions on ecological footprint. This chapter have difference patterns observed in the estimated coefficients across different estimators and it might be an important evidence to determine the implications for ecological footprint. Additionally, this chapter highlighted the importance and why it is appropriate to apply PMG model, as validated through the Hausman test, this test is crucial to inspect if the PMG is effective in capturing the long-term homogeneity of ecological footprint in EU countries.

4.1 Data Analysis

The panel estimation has come with the results and has been summarized in Table 4.1.1 To make comparison, results estimated from PMG, MG and DFE estimators are presented to show the best and most appropriate outcome.

Table 4.1.1: Panel estimations

Equation	PMG	MG	DFE
Long run coefficients			

ECON	0.5706***	0.7117***	0.4334***
NR	-0.0047	0.0322	-0.0098
HDI	0.5783***	2.0927***	0.7054***
SMR	0.0110	-0.0220	-0.0037
Error Correction (π_i)	-0.4709***	-0.8542***	-0.3995***
Short run coefficients			
ΔECON	0.1968***	-0.2863	0.2170
ΔNR	0.0498***	0.0315**	0.0410***
ΔHDI	2.4063***	1.7785**	2.5061***
ΔSMR	0.0049	0.0362	-0.0157***
Log likelihood	1043.654	-	-
Number of parameters estimated	25	25	25
Observations	600	600	600

*Notes: ***, ** and * indicate significant 1%, 5%, and 10% significance levels, respectively.*

Distinctive patterns have been shown in the estimated coefficients for both short-run and long-run relationships on different estimators. In the long-run analysis, the PMG showed significant positive coefficients for energy consumption at 1% significant level. This indicates that energy consumption does have a substantial impact on ecological footprint. Along we recorded the positive effects of human development on the ecological footprint at 1% significant level as well. On the other hand, the coefficient for renewable energy transition has shown a positive coefficient but is not statistically significant, this reflects potential ineffectiveness in reducing ecological footprint in the long term. For MG, it exhibited a notably high coefficient for energy consumption at 0.7117 and human development at 2.0927, showing amplified effects compared to what we obtained from the PMG result. Additionally, MG displayed a negative coefficient for renewable energy transition at -0.220, showing an inverse relationship between ecological footprints. Meanwhile, for DFE, it provides a more conservative estimation with 1% significant coefficient for energy consumption at 0.4334, human development at 0.7054, and a non-significant coefficient for natural resources consumption at -0.0098 and renewable energy transition at -0.0037, respectively. The overall results suggest a cautious approach to understanding the long-run dynamics, it is undeniable that energy consumption and human development on ecological footprint have potential impacts on ecological footprint and the impact of natural resources consumption and renewable energy transitions in the long run might be overestimated.

For short-run analysis, the results from PMG estimators exhibited significant coefficients for energy consumption, natural resources consumption, and human development, at 1% significant level, this result highlights the importance of these variables in shaping ecological footprint dynamics over short-run periods. However, the coefficient obtained from renewable energy transition shows an insignificant coefficient. Conversely, the MG estimator has presented contrasting results. For energy consumption, it shows a negative coefficient of -0.2863, which suggests potential inconsistencies in estimation as energy consumption showed a reduction in ecological footprint. For natural resources consumption and human development, it displayed positive coefficients of 0.0315 and 1.7785 at 5% significant level respectively, notably that it showed divergent short-run effects compared to the other estimators. For renewable energy transition, similar to PMG, it showed an insignificant coefficient at 0.0362. For DFE, the natural resources consumption and human development exhibit similar results as PMG estimators, with 1% significant level at the positive coefficient of 0.0410 and 2.5061 respectively. However, energy consumption, it shows an insignificant coefficient in influencing ecological footprint. Lastly, the renewable energy transitions show a negative coefficient of -0.0157 at 1% significant level, indicating there is an inverse relationship between the adoption of renewable energy and the ecological footprint.

Finally, the results of the Hausman test established that PMG had consistency and efficiency compared to MG. Therefore, the selection of PMG to capture the energy consumption, natural resource use, human development, and renewable energy transition in the European countries was well supported due to both short-run and long-run relationships. The PMG model appeared to provide a more complete picture of the dynamic relationships between the identified factors in ecological footprint management and sustainable development approaches.

4.2 Conclusion

To conclude, the conducted panel estimation analysis in this chapter yielded a clear result of the European country's ecological footprint factors. Using a broad range of estimators that would give us an analysis of variables in the short run and long-run, we identified the effects of energy consumption, natural resources, and human development on the ecological footprint and renewable energy breaks. Overall, our findings suggest that while caution should be taken about overestimating some of the explained variables with long-term dynamics, short-term dimensions signify energy consumption and human development is more instrumental in how ecological footprint dynamics in the short term are progressing. Such results give detailed orientation to policy developers and actors targeting environmental practices and healthy economic growth over the years. We will further discuss the underlying factors and implications in the next chapter using the revealed results.

CHAPTER 5: DISCUSSION, CONCLUSION AND IMPLICATIONS

5.0 Introduction

In this chapter, we will discuss the relationship between the relationship between energy consumption, natural resources consumption, human development, renewable energy transition, and their impact on ecological footprint in European Union (EU) countries. Through empirical evidence and theoretical frameworks, this article will further explore the associations between these factors. Through the findings, we hope to explain the importance of environmental sustainability and also future policy implications. Moreover, we also provided some insights, including the study's limitations, and future research recommendations to help further research in illuminating the dynamics of the ecological footprint and each country's policies to tackle this issues.

5.1 Discussion

In European Union countries, energy consumption is a key determinant of the ecological footprint which represents the intricate relationship between human activities and their resultant environmental impact. The significant and positive association between energy consumption and ecological footprint can be explained through empirical evidence and theoretical frameworks. Energy consumption is a major contributor to ecological footprints in Europe, due to the extensive dependence on fossil fuels and the relatively extraction-intensive process. Fossil fuels are a major source of greenhouse gas emissions due to the use of the burning process to generate electricity. This process releases carbon dioxide gas into the atmosphere exacerbating the greenhouse effect and further contributing to climate change. Not only do these environmental fundamentals contribute to the accumulation of a high ecological footprint but also create sustainability challenges like air pollution, the destruction of habitats, and the wiping out of biodiversity. There emerges an urgent realization among policymakers on the need to reduce the ecological footprint hence the call for a joint effort to support energy reduction strategies or the adoption of renewable energy. Renewables such as wind, solar, and hydroenergy sources will diversify the energy mix and reduce reliance on limited and unsustainable fossil fuels. Such a change in energy generation resources will support reduced ecological footprints and promote sustainability and renewable energy.

The relationship between natural resource consumption and ecological footprint across European countries seems to be multifaced. Although the short-run significance of natural resource consumption against ecological footprint demonstrates the negative effects of overconsumption and excessive natural resource exploitation, the insignificance, in the long run, requires further investigation to understand the dynamics. Initially, the rapid pace of economic growth and industrialization led to increased natural resource demand, accelerating the rate of ecosystem degradation and ecological footprint. However, as economic development becomes more saturated due to the further maturation of economies and consistent trends, natural resource consumption may follow the same path of replenishment and balance. Therefore, the long-run effect of natural resource consumption on ecological footprint can be balanced out. The same can be said about the reduced natural resource dependency due to the increased usage of renewable energy and environmentally friendly technologies. Good management of resources and environmentally friendly natural resource conservation strategies must be a focus of European countries' ecological policies to avoid significant long-run negative effects of natural resource consumption.

In European countries, human development can be measured as advancements in education, healthcare, and living conditions. All of them are considered significant contributors to the ecological footprint. The positive sign of the coefficient indicates that human development contribution to ecological footprint is multifaceted and vast. It is a confirmed theory that as countries have improved human development, the consumption habits and use of resources also increase, leading to a greater ecological footprint. This tendency is especially true in the short run, as rapid economic expansion, and urbanization drive commerce, exposing rapid and severe environmental exploitation. In the long run, although the positive correlation between human development and the ecological footprint continues to exist, the strength of this correlation might peak and fall. This is due to society progressively embracing more sustainable methods and raising public knowledge of environmental concerns. With education, intervention, and innovation, European countries can successfully address the trade-off between human development and ecological footprint, maintaining a balance between societal advancement and conservation. This theory of the environmental Kuznets curve can explain this phenomenon. As the economy becomes mature and societies become more civilized following human development, the initial effects of human development on ecological footprint can be mitigated through mutual sustainable effort.

The insignificant coefficient of renewable energy transition in explaining ecological footprint in the short and long run shows that it is still ineffective in mitigating ecological footprint. The promising nature of renewable energy technologies in reducing the ecological footprint and minimizing the dependence on fossil fuels depends on several factors. In the short run, the adoption of renewable energy can be due to several limitations, such as expensive implementation costs, technological limitations, and a lack of existing infrastructure to support the use of renewable energy. Most importantly, many other challenges, such as interest and institutional confrontations, might be a stepping-stop for renewable energy transition. In the long run, there is a need to overcome the above obstacles and ensure that renewable energy is actively adopted to ensure that reducing the ecological footprint is meaningful. At national, regional, and even global levels, all countries need to work together to utilize sustainable energy sources. Countries need to work together to accelerate this transition, facilitate innovation, and eliminate obstacles. European Union countries can use renewable energy as a sustainable development foundation to offer a cleaner, secure, and secure future for their upcoming generations.

5.2 Implications of the Study

The positive correlation of energy consumption with ecological footprint in the observed EU countries indicates that government action is required to have energy policy intervention. First of all, EU countries should control the current level of energy consumption and to encourage the shift to renewable sources of energy. Incentives for adopting solar and wind power installations should also be implemented, for both individual and business usage purposes. Governments should also strive to attract more FDI in the renewables sector to speed up the development and implementation of clean technologies. The phasing out of the use of fossil fuels should be done gradually using proper incentives and regulations. Sustainable management of resources and adoption of circular economy principles should also be encouraged to reduce ecological footprint across all business sectors. Thus, the EU countries should shape their energy policies in a way that reflects the objectives of sustainability, ensuring a shift to cleaner sources of energy while tackling other environmental issues, without interfering with the importance of economic growth.

Economic development is a key factor for higher living standards and general welfare. At the same time, without strategic planning, it is unreliable from the point of view of the sustainability and environmental friendliness of growth. In particular, EU countries should not face a choice between economic growth and environment protection but should incorporate the goals of environmental sustainability into the strategies of development. Similarly, human development should include environmental knowledge and sustainability as a factor of development, along with the current quality of life and level of consumption. Governments should also fund awareness advertisement and engagement programs, targeting the general population with information campaigns, and utilizing community initiatives to promote ecological footprints and sustainable consumption. Furthermore, cooperation with all stakeholders, including their neighbors and international organizations, is also a key to the overall success in empowering the sustainable goals of the EU regions. Economic growth no longer focuses on a single direction, that is performance, but also requires countries' efforts to maintain sustainability to remain competitive globally and a long-term success.

5.3 Limitations of the Study

The limitations of this study are the exclusive focus on EU countries, which limits the applicability of the identified patterns to regions with different socio-economic, environmental, and policy contexts. The differences in the drivers of ecological footprint in different regions call for cautious generalization of the results beyond the European Union context, as well as emphasizing the importance of specific contextual characteristics in the interpretation of the results offered by this study. Also, there is a possibility of endogeneity, including omitted variables, which may be present in the estimated relationships that require additional study to identify potentially relevant factors as control variables to achieve more accurate results publication. These limitations should be addressed to contribute to an understanding of ecological footprint change and achieve evidence-based policy-making on a global level.

5.4 Recommendations for Future Research

Future researchers need to develop comparative studies across different regions based on the variations in the determinants of the ecological footprint and differences in the impacts of the developed and implemented policy interventions. It would be beneficial for future research to compare EU countries to other regions, such as Asian countries, as their socioeconomic profiles and growth paths can provide new knowledge on the factors influencing the ecological footprint. Researchers should also employ multi-level analysis approaches to better consider the ecological footprint dynamics on different levels, including national, regional, and local. Multi-level models are beneficial in capturing the relations between the variables more clearly and accounting for the context on the levels of geographic difference levels and geographical areas. It might help providing accurate modelling and interpretation of data where observations are not fully independent (Hox et al., 2017).

5.5 Conclusion

The analysis of energy consumption, natural resource consumption, and human development indicates the nature of the contribution of these factors to the formation of ecological footprints in EU countries. Energy consumption, based on the use of fossil fuels, is the factor out of these three that makes a more substantial contribution to harming the environment and renewable energies transition is crucial to tackle the ecological footprint issues. While current renewable energies show high potential of implementation, the framework for their usage is challenging, and it appears unlikely that renewable energies will become a full alternative for nonrenewable energy sources in the near future. Meanwhile, the relationship between human development and ecological footprint indicates the need for sustainability-focused integrated development.

The findings and arguments presented in this study have important implications for practice and public policy that demand action by governments to prioritize renewable energy, responsible resource management, and sustainable development. In addition, the study has stated the limitations where it emphasizes the need for further and robust research in drawing inferences on similarly situated or different compounding regions. Researchers can further conduct comparative studies in various regions, using multi-level analysis, and assume the implementation of policy interventions to focus on promoting evidence-based decision-making and global sustainability. If these recommendations are implemented and the obtained results are developed in the future research, policymakers and researchers can collaboratively work towards achieving a more sustainable future for everyone.

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