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Thesis

**Impact of Green Finance on Economic Growth:
Evidence from the European Union Countries**

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Impact of Green Finance on Economic Growth: Evidence from the European Union Countries

Abstract

The current study examines the relationship between the economic growth and the green finance in European Union countries in which Germany, France, Sweden, Denmark, Luxembourg, the Netherlands and Finland are taken. The data has been collected from 2012-2024. In current study green bonds issuance and renewable energy investment are taken to measure the green finance while trade openness, unemployment and inflation are taken as control variables. For the analysis, descriptive statistics, correlation matrix, pooled ordinary least squares, country and the year fixed-effects robustness models and the quantile regressions at the 25th, 50th and the 75th conditional quantiles are used for the GDP growth. The broader quantile analysis used to measure the possible measures to compare the relatively weak, typical and the stronger growth conditions. The result of current study shows that the renewable energy investment shows positive coefficient for all the three quantiles while the estimates are not statistically significant. The result shows that the issuance of green bond shows the negative and insignificant results at the lower quantile, while positive at the median, and weak statistical evidence at the upper quantile. Inflation is negatively associated with growth, particularly in the lower and median parts of the conditional distribution. Trade openness becomes positive and statistically significant in the upper green-bond specification. The pooled OLS estimates are small and statistically insignificant. Country fixed effects, year fixed effects, and two-way country-and-year fixed effects lead to the same substantive conclusion: neither renewable energy investment nor green bond issuance is statistically significant in the annual growth models. Overall, the findings indicate that green finance may support economic growth, but its effect is not automatic and depends on the economic

environment, project quality, institutional credibility, and the time required for investment to influence productive capacity.

Keywords: Green finance; Green bonds; Renewable energy investment; Economic growth; Quantile regression; European Union.

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CHAPTER 1

INTRODUCTION

In recent decades, the global transition towards sustainable development has gained increasing importance because of the need to reduce greenhouse-gas emissions, strengthen energy security, and address climate change. Renewable energy sources, including wind, hydropower, biomass, and solar energy, have therefore become important not only for environmental objectives but also for economic development. Developing countries are among the world's fastest-growing economies and major energy consumers, which highlights the close relationship between economic development and investment in green energy. European countries have been at the forefront of the green-energy transition, supported by increasing domestic and foreign investment, stronger policy frameworks, and ambitious renewable-energy targets (IRENA, 2023).

Renewable energy investment is increasingly viewed as a potential driver of economic activity and investment. According to the IEA (2021), investment in renewable energy can generate substantially more employment than comparable investment in fossil fuels. Renewable energy investment can also reduce exposure to energy-price volatility, lower dependence on imported fuels, and foster innovation in green technologies. Popp et al. (2020) show that strategic investment in renewable energy in countries such as the United States, China, and Germany can stimulate economic activity while contributing to reductions in carbon emissions.

Within the global financial system, green finance has emerged as an important development in the pursuit of sustainable development and climate objectives. In the European Union, green finance can influence economic activity while also helping to reduce environmental risks and providing relevant information to policymakers and investors. The European Union has committed to

achieving climate neutrality by 2050. According to the European Commission (2024), green finance is central to this economic transformation because the financial system must respond to climate change, resource scarcity, and the need for sustainable innovation. Green-finance instruments include sustainable loans, ESG funds, and green bonds, which can support projects aimed at reducing carbon emissions, improving energy efficiency, and strengthening resilience to climate-related shocks (European Parliament, 2025).

The historical development of green finance also demonstrates the importance of government involvement in economic planning and environmental policy. The Paris Agreement and the Kyoto Protocol have encouraged countries to integrate climate objectives into economic and financial policies. The European Investment Bank has played an important role in supporting sustainable infrastructure and renewable-energy projects in member states (OECD, 2024). Since the early 2010s, the European Union has been a major participant in the global green-bond market, with countries such as the Netherlands, France, and Germany developing climate-resilient infrastructure and green-finance markets (Lu et al., 2025). A major turning point came in 2019 with the European Green Deal, which strengthened the commitment to climate neutrality and emphasized the role of finance in mobilising large-scale sustainable investment. In response to the COVID-19 pandemic, the EU launched the NextGenerationEU recovery plan, further strengthening green funding and embedding sustainability within the European economic recovery strategy (European Central Bank, 2025).

Understanding the factors that affect economic growth requires a clear theoretical foundation for the role of green finance. Endogenous growth theory emphasizes innovation and investment as drivers of long-term growth. Investment in sustainable technologies and environmentally friendly infrastructure can increase productivity and competitiveness and may stimulate economic activity

through greater green investment (Hu & Gan, 2025). Institutional economics highlights the importance of regulatory quality, institutional capacity, and governance in determining the effectiveness of green finance. Strong institutions can reduce the risk of misallocation and improve the allocation of green funds to productive uses (Springer, 2023). Environmental economics focuses on internalising environmental externalities through mechanisms such as incentives for sustainable practices and carbon pricing. In addition, financial intermediation theory emphasizes the role of banks and capital markets in channeling funds from savers to investors; green finance can direct capital towards projects that generate both economic and environmental returns (OECD, 2024).

The relationship between economic growth and green finance is promising but complex. Renewable energy investment can contribute to green finance by reducing dependence on fossil fuels, improving energy security, and supporting the creation of new industries. It can also improve productivity and quality of life through energy-efficient buildings, sustainable transport, and smart-city infrastructure. Over the longer term, green investment can strengthen competitiveness, encourage research and development, and generate employment in manufacturing, construction, and related services. Strong green-finance systems may also improve economic resilience to climate-related disruptions (European Central Bank, 2025). Empirical evidence from EU countries generally indicates positive potential outcomes, although the strength of the relationship differs across countries. Nordic economies have often combined growth and sustainability more successfully, whereas weaker institutional frameworks can constrain outcomes in some Eastern European countries (Lu et al., 2025).

The European Union has developed a robust policy architecture to support green finance. The European Green Deal provides a framework for achieving climate neutrality by 2050. The EU

Taxonomy establishes a classification system for sustainable economic activities, while the Sustainable Finance Disclosure Regulation requires financial-market participants to provide information about sustainability risks and investments (Lu et al., 2025). Recent literature suggests that economic growth may be stronger in EU countries with greater green-finance activity, particularly where institutional quality is high (Springer, 2023). However, substantial heterogeneity remains across member states. Strong financial and governance structures in Nordic markets may support a more positive relationship, while limited institutional capacity can constrain the effectiveness of green finance elsewhere. The effectiveness of green finance therefore depends on market maturity, regulatory frameworks, and institutional quality, as also discussed by Hu and Gan (2025) in their comparative study of the United States and China.

Several interconnected mechanisms can explain how green finance may support long-term economic growth. Endogenous growth theory emphasises human-capital accumulation, innovation, research and development, and technological progress as foundations of economic expansion. By channeling resources into sustainable infrastructure and renewable-energy technologies, green finance can support these mechanisms. Such investment may increase productivity and competitiveness while reducing environmental externalities. Knowledge spillovers, technological progress, and financing for clean technologies are central elements of endogenous growth models (Hu & Gan, 2025). In the European Union, allocating green funds to research, development, and renewable-energy sectors can therefore reinforce the endogenous growth mechanism (Lu et al., 2025).

Green finance has become an important topic within the European Union's sustainability agenda, but important gaps remain in the academic and policy literature. Recent studies provide evidence on green finance and environmental outcomes, while the direct relationship between green finance

and economic growth remains less clearly established. Khan et al. (2025) examine the relationship between renewable-energy adoption and GDP growth and identify a need for further research on renewable-energy investment and GDP growth in the EU context. Zhou and Chen (2024) focus on environmental outcomes and carbon emissions and argue for broader research into the macroeconomic implications of green finance.

Heterogeneity across EU member states also creates an important research gap. Petrova and Dimitrov (2025) examine regulatory frameworks, financial-market maturity, and governance quality but do not directly estimate the impact of green finance across different EU economies. Their findings suggest that countries with weaker institutional capacity may struggle to translate green investment into measurable economic outcomes, whereas countries such as Sweden and Germany, with stronger financial systems, may experience more favourable growth effects. Alvarez and Rossi (2024) examine the EU Taxonomy and highlight inconsistencies in how financial institutions classify and report green investments. Such inconsistencies create challenges for empirical research and motivate the present study. Accordingly, this study examines the relationship between green finance and GDP growth in selected EU countries that have substantial green-finance activity, established policy frameworks, and sufficiently consistent data.

Green finance has therefore become a cornerstone of the European Union's climate-neutrality strategy, although its economy-wide implications remain uncertain. The EU Taxonomy and the Sustainable Finance Disclosure Regulation provide frameworks for sustainable investment and can strengthen the connection between financial activity and environmental objectives (European Environment Agency, 2024). Green finance can also support innovation, energy transition, long-term productivity, and economic growth (Hu & Gan, 2025). At the same time, the growing global interest in green finance has highlighted challenges related to definitional ambiguity, uneven

institutional quality, and greenwashing, all of which may reduce the effectiveness of green finance in promoting sustainable economic development (Krastev & Krasteva-Hristova, 2024).

The uneven effectiveness of green finance creates challenges for policymakers and investors. Achieving both economic-growth and sustainability objectives requires addressing inefficient resource allocation, possible misallocation of funds, and weaknesses in project implementation. Nordic countries have been relatively successful in leveraging green finance, whereas countries with more limited institutional capacity and weaker governance structures may face greater difficulties (Lu et al., 2025). Zhang et al. (2023) and Akomea-Frimpong et al. (2022) also highlight the substantial financing requirements associated with achieving sustainable-development goals. These challenges demonstrate the importance of generating country-level empirical evidence on whether green-finance activity is associated with measurable economic outcomes.

The central problem addressed by this study is the lack of comprehensive EU-focused empirical evidence on the relationship between green finance and GDP growth. Understanding the economic consequences of green finance is important for evaluating both sustainability risks and opportunities for economic resilience and climate neutrality (European Central Bank, 2025). This study therefore systematically examines the relationship between green finance and GDP growth in selected European Union countries and provides evidence relevant to policymakers, financial institutions, and researchers.

The main research questions of the current study are:

- I. What is the impact of renewable energy investment on GDP growth in EU countries?
- II. What is the impact of green bond issuance on GDP growth in EU countries?

The main research objectives of the current study are:

- I. To examine the impact of renewable energy investment on GDP growth in EU countries.
- II. To examine the impact of green bond issuance on GDP growth in EU countries.

The current study addresses the question of how green finance affects GDP growth in selected European Union countries. The EU has ambitious climate-neutrality targets, yet limited empirical evidence explains how green finance translates into measurable economic outcomes. By examining this relationship empirically, the study provides evidence relevant to financial institutions, academics, and policymakers. From a policy perspective, the findings can inform the implementation of frameworks such as the EU Taxonomy and the European Green Deal and can contribute to the discussion of how green-finance markets may support economic growth. The study also provides implications for investment strategies and for financial institutions involved in sustainable lending and green bonds. More broadly, it contributes to the literature on financial intermediation, environmental economics, and economic growth.

CHAPTER 2

LITERATURE REVIEW

2.1 Structure of the Literature Review

This chapter reviews the relationship between green finance and economic growth in three connected stages. First, it discusses green finance as the broad framework through which capital is directed towards environmentally sustainable activities. Second, it focuses on renewable energy investment, which represents the actual allocation of funds to projects such as solar, wind, hydropower, and related infrastructure. Third, it examines green bonds, which are financing instruments used by governments, financial institutions, and firms to raise capital for eligible green projects. Renewable energy investment therefore captures project implementation, whereas green bonds capture a channel through which such projects may be financed. The chapter then presents the theoretical framework and develops the research hypotheses.

2.1.1 Green Finance and GDP Growth

Green finance has become an important component of sustainable development because it connects financial decision-making with environmental objectives. It includes instruments and activities such as green bonds, sustainable lending, environmental funds, and investment in low-carbon technologies (Lindenberg, 2014; Bhattacharyya, 2022). Its economic relevance is commonly explained through the reallocation of capital towards cleaner infrastructure, technological innovation, energy efficiency, and activities that may improve long-term productivity.

Theoretical research generally supports a positive relationship between environmentally oriented finance and economic performance. Endogenous growth theory emphasizes knowledge accumulation, innovation, and investment as sources of long-term growth (Romer, 1990). Porter and van der Linde (1995) further argue that well-designed environmental policies can stimulate innovation and improve competitiveness, while Aghion et al. (1998) show how investment and technological change can support productivity. From this perspective, green finance may promote growth when it reduces financing constraints and directs resources towards productive and innovative sectors.

Empirical evidence, however, is mixed. Studies on developing and emerging economies frequently report positive effects through industrial upgrading, employment creation, and technology adoption (Zhang & Zhou, 2016; Al Mamun et al., 2018). Evidence for advanced economies is less uniform because ageing populations, mature infrastructure, slower productivity growth, and service-based economic structures may reduce the size or speed of the economic gains. Marques and Fuinhas (2012) find that renewable energy benefits may take time to materialize, while Mertzanis et al. (2019) report limited short-run growth effects from ESG-related finance.

The effectiveness of green finance also depends on institutional and market conditions. Information asymmetries, verification costs, weak disclosure, and inconsistent definitions of green activities can reduce the efficiency of capital allocation (Weber, 2010; Alvarez & Rossi, 2024). Green bonds may lower financing costs and improve risk diversification without immediately producing a measurable macroeconomic effect (Baker et al., 2018; Agliardi & Agliardi, 2019; Banga, 2019). Accordingly, the literature suggests that green finance can support economic growth, but its impact depends on regulatory quality, market maturity, project implementation, and the time required for investment to affect productive capacity.

2.1.2 Renewable Energy Investment and GDP Growth

Renewable energy investment is a specific component of green finance and refers to expenditure on the development and expansion of renewable energy projects and technologies. Unlike the broader concept of green finance, it reflects the actual deployment of capital into productive assets. Such investment may affect GDP growth by increasing energy capacity, creating employment, supporting technological innovation, reducing dependence on imported fossil fuels, and improving energy security (Popp et al., 2011; Polzin, 2017).

The empirical literature reports both positive and weak effects. Payne (2011), Tiwari (2011), and Bhattacharya et al. (2016) find that renewable energy can support long-run economic activity, while Magnani and Vaona (2011) identify positive regional spillovers in Italy. In contrast, Ewing et al. (2007) and Ohler and Fetters (2014) show that the effect varies across technologies and economic contexts. The evidence therefore indicates that renewable energy investment is not automatically growth-enhancing; its effectiveness depends on policy stability, financing conditions, technological maturity, and institutional quality (Sen & Ganguly, 2017; Semieniuk et al., 2021).

Cross-country studies also suggest that the relationship differs according to the level of development. Khan et al. (2014) report stronger energy-growth links in low- and middle-income economies than in high-income OECD countries. Apergis and Payne (2010, 2012) find evidence of bidirectional relationships in several country panels, implying that renewable energy can stimulate growth while economic expansion also raises energy demand. Overall, the literature supports a potentially positive effect, but also shows that the size and timing of the effect are heterogeneous across countries.

2.1.3 Green Bonds and GDP Growth

Green bonds are fixed-income instruments whose proceeds are earmarked for environmentally sustainable projects. They differ from renewable energy investment because they represent a financing mechanism rather than the investment project itself. Green bonds can mobilize long-term capital for renewable energy, energy-efficient infrastructure, low-carbon transport, waste management, and climate-resilience projects (Zerbib, 2019; Flammer, 2021). Their contribution to economic growth may operate through lower financing costs, greater availability of capital, additional investment, employment creation, and technological upgrading.

The literature nevertheless cautions that growth in green bond issuance does not necessarily imply an equivalent increase in productive green investment. Market liquidity, verification standards, investor preferences, and the credibility of environmental claims affect whether bond proceeds generate real economic transformation (Campiglio, 2016; Krogstrup & Oman, 2019). Studies such as Baker et al. (2018), Agliardi and Agliardi (2019), and Banga (2019) find that green bonds provide financing and diversification benefits, although their direct macroeconomic impact may be gradual or modest.

In the European Union, stronger regulatory frameworks and developed capital markets may improve the ability of green bonds to finance productive projects. Green bond-funded investment can support capital formation, employment, energy security, and reduced exposure to fossil-fuel price volatility (Weber, 2017; OECD, 2022). The expected growth effect therefore depends on whether issuance is translated into credible, additional, and efficiently implemented investment.

2.2 Theoretical Framework

The relationship between green finance and economic growth is explained through endogenous growth theory, environmental economics, institutional economics, and financial intermediation theory. Endogenous growth theory predicts that investment in innovation, infrastructure, knowledge, and technology can raise productivity and long-term output. Renewable energy investment may contribute through these channels by expanding productive capacity and encouraging cleaner technological development.

Environmental economics explains green finance as a mechanism for addressing environmental externalities. By incorporating climate and pollution risks into financial decisions, green financing can redirect capital towards projects that produce both private economic returns and wider social benefits. Financial intermediation theory emphasizes the role of banks and capital markets in screening projects, reducing information asymmetries, monitoring borrowers, and transferring funds from savers to productive investment. Green bonds are relevant to this mechanism because they provide a dedicated channel for financing eligible environmental projects.

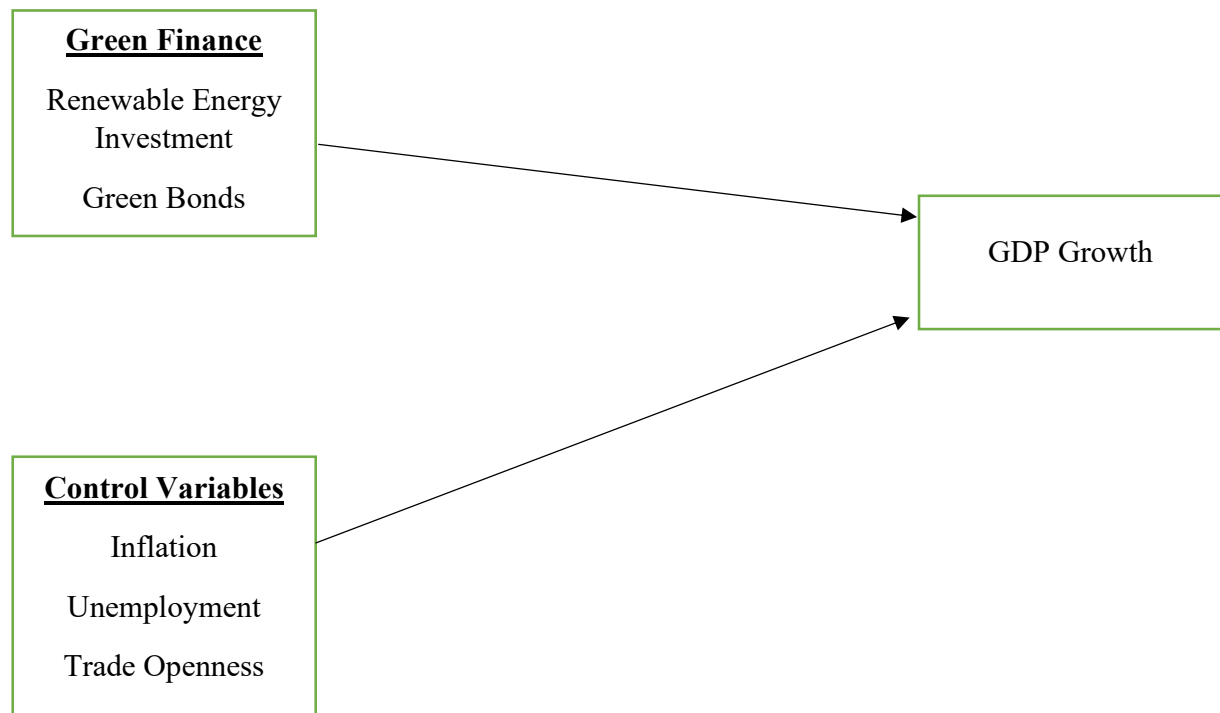
Institutional economics highlights that these mechanisms are more effective when governance, disclosure standards, regulatory quality, and enforcement are strong. The expected impact of green finance is therefore conditional on the ability of institutions and financial markets to ensure that funds are allocated to credible and productive projects. In this study, renewable energy investment measures project-level capital deployment, while green bonds measure a market-based financing channel. Inflation, unemployment, and trade openness are included to account for other macroeconomic influences on GDP growth.

2.3 Research Hypotheses

Based on the theoretical arguments and empirical evidence reviewed above, the study tests the following hypotheses:

H1: Renewable energy investment has a positive effect on GDP growth.

H2: Green bond issuance has a positive effect on GDP growth.



CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Approach

This study adopts a quantitative explanatory research design to examine the relationship between green finance and GDP growth. It uses annual secondary data organised as a country-year panel. Renewable energy investment and green bond issuance are the principal explanatory variables, GDP growth is the dependent variable, and inflation, unemployment, and trade openness are included as controls. Descriptive statistics and correlations summarise the data, pooled OLS provides a benchmark estimate of average relationships, and median quantile regression provides a robustness-oriented estimate that is less sensitive to outliers and heteroskedasticity.

3.2 Study Population, Sample and Period

The population consists of the 27 European Union member states. The empirical sample used in the principal analysis includes Germany, France, the Netherlands, Sweden, Denmark, Luxembourg, and Finland for 2012–2024, giving a balanced panel of 91 country-year observations. The sample is purposive rather than random and was constructed around countries for which the available green-finance, renewable-energy-investment, macroeconomic, and GDP series could be aligned consistently over the same annual period. These countries also provide meaningful variation in economic size, financial-market depth, trade exposure, energy structure, and renewable-energy development. An extension to additional European countries was considered in response to the review of the thesis. However, the dataset supplied for the present study contains only the seven-country balanced panel, and the available documentation does not

provide a harmonised country-level series for renewable-energy investment and green-bond issuance for additional countries. Adding countries without rebuilding these variables from the same underlying definitions and sources would create measurement inconsistency and could make the enlarged sample less comparable than the existing one. Accordingly, the revised thesis does not claim that the seven-country sample is representative of the European Union. Instead, it treats broader country coverage as a clearly defined extension for which comparable data must first be assembled. The recommended extension is to add further European countries for which the same annual definitions, units, and source methodology can be reproduced, and then re-estimate all principal models, including pooled OLS, quantile regression, country fixed effects, year fixed effects, and two-way fixed effects. This approach directly addresses the reviewer's concern about heterogeneity while avoiding the introduction of inconsistent measurements.

3.3 Data Collection

The study uses annual secondary data obtained from established international databases, including the World Bank's World Development Indicators, Eurostat, OECD sources, and the databases used for green bond and renewable energy investment series. The same definition and unit are applied consistently across countries and years. Where the renewable energy investment series aggregates investment by sector rather than by investor type, it is treated as total recorded investment and may include both public and private financing. This limitation is acknowledged because the available series does not permit a consistent separation of public and private investment for all sampled countries and years.

3.4 Variable Definitions and Measurement

The dependent variable is annual GDP growth. Green finance is represented by renewable energy investment and green bond issuance. Inflation, unemployment, and trade openness are included as control variables. The definitions, measurement units, and expected relationships are explained below.

3.4.1 Renewable Energy Investment

Renewable energy investment refers to recorded financial commitments to renewable energy projects and technologies, including solar, wind, hydropower, biomass, and related infrastructure (Polzin, 2017). The variable is transformed into its natural logarithm (LNREI) to reduce skewness and make large cross-country differences more manageable. The underlying series is treated as total recorded investment and may contain both public and private components where the source does not provide a consistent investor-level breakdown.

3.4.2 Green Bonds

Green bonds are fixed-income securities issued by governments, corporations, or financial institutions to finance or refinance eligible environmentally sustainable projects (Flammer, 2021). The variable measures annual green bond issuance in the unit reported by the source and captures the scale of market-based green financing available in each country.

3.4.3 GDP Growth

GDP growth is the annual percentage change in real gross domestic product and represents the expansion or contraction of economic activity (World Bank, 2022). It is used as the dependent

variable because it provides a comparable measure of annual macroeconomic performance across countries.

3.4.4 Control Variables

Three control variables are included to reduce omitted-variable bias and separate the association of green finance from other macroeconomic influences on growth.

Inflation

Inflation is measured as the annual percentage change in the general price level. It is included because high or unstable inflation can reduce purchasing power, increase production and financing costs, create uncertainty, and discourage investment, thereby affecting GDP growth (Barro, 1995; Blanchard, 2017).

Unemployment

Unemployment is measured as the percentage of the labour force that is without work, available for work, and actively seeking employment. It is included because labour underutilisation can reduce production, household income, consumption, and aggregate demand, all of which are related to economic growth (Blanchard & Diamond, 2010; ILO, 2021).

Trade Openness

Trade openness is measured as the sum of exports and imports as a percentage of GDP. It is included because access to international markets can influence productivity, competition, technology transfer, investment, and demand for domestic output (Dollar, 1992; Frankel & Romer, 1999).

3.5 Econometric Specification

Two models are estimated to examine the separate effects of renewable energy investment and green bond issuance while retaining the same control variables. Model 1 relates GDP growth to LNREI, inflation, unemployment, and trade openness. Model 2 relates GDP growth to green bond issuance, inflation, unemployment, and trade openness. In both models, i denotes country, t denotes year, the constant captures the intercept, and the error term captures unobserved influences on GDP growth.

$$\text{Model 1: } \text{GDPG}_{it} = \alpha + \beta_1 \text{LNREI}_{it} + \beta_2 \text{INF}_{it} + \beta_3 \text{UNEMP}_{it} + \beta_4 \text{TO}_{it} + \varepsilon_{it}$$

$$\text{Model 2: } \text{GDPG}_{it} = \alpha + \beta_1 \text{GB}_{it} + \beta_2 \text{INF}_{it} + \beta_3 \text{UNEMP}_{it} + \beta_4 \text{TO}_{it} + \varepsilon_{it}$$

3.6 Econometric Methodology

3.6.1 Stationarity Test

The stationarity properties of the series are examined using the Augmented Dickey-Fuller test with an intercept. The null hypothesis is that the series contains a unit root, while the alternative is stationarity. The test is used to reduce the risk of spurious relationships. Because the dataset is a multi-country panel, the results should be interpreted as a preliminary diagnostic; panel unit-root tests would provide an additional robustness check in future work.

3.6.2 Pooled Ordinary Least Squares

Pooled OLS is estimated as a benchmark model of the average conditional relationship between the explanatory variables and GDP growth. It provides coefficients that can be compared with the

median quantile estimates, although it does not explicitly model unobserved country-specific heterogeneity.

3.6.3 Quantile Regression

The study estimates quantile regression at the 0.25, 0.50, and 0.75 quantiles. These points represent the lower, median, and upper parts of the conditional distribution of GDP growth. Quantile regression is useful because it is less sensitive to extreme values than ordinary least squares and does not require the effect of each explanatory variable to be identical across the full growth distribution. The estimates are interpreted as conditional associations rather than causal effects. The 0.25 quantile describes observations located in the lower part of the conditional growth distribution, the 0.50 quantile represents the conditional median, and the 0.75 quantile represents the upper part. These terms do not refer to fixed groups of countries because the same country may appear in different parts of the distribution in different years.

3.6.4 Country and Year Fixed Effects

As a robustness check, the study also estimates fixed-effects specifications. Country fixed effects control for time-invariant characteristics that differ across countries, such as persistent institutional structures, geography, long-standing energy systems, and financial-market characteristics. Year fixed effects control for shocks common to all sampled countries in a given year, including the COVID-19 disruption, the European energy-price shock, changes in common financial conditions, and broad inflationary pressures. A two-way fixed-effects specification combines both sets of controls. These models are used to assess whether the weak pooled relationships are driven by

unobserved country heterogeneity or common time shocks. The fixed-effects estimates are interpreted as robustness tests of the main annual relationships rather than as proof of causality.

Model 1 with two-way fixed effects: $GDPG_{it} = \alpha_i + \lambda_t + \beta_1 LNREI_{it} + \beta_2 INF_{it} + \beta_3 UNEMP_{it} + \beta_4 TO_{it} + \varepsilon_{it}$

Model 2 with two-way fixed effects: $GDPG_{it} = \alpha_i + \lambda_t + \beta_1 GB_{it} + \beta_2 INF_{it} + \beta_3 UNEMP_{it} + \beta_4 TO_{it} + \varepsilon_{it}$

3.6.5 Lagged Green-Finance Variables

To examine the possibility that green-finance investment affects GDP growth with a delay, an additional robustness specification is proposed using one-year and two-year lags of the two main green-finance variables. This extension is motivated by the fact that renewable-energy projects require planning, financing, construction, connection, and operational phases, while green-bond proceeds may also be spent over more than one fiscal year. The lagged specifications therefore test whether the association with GDP growth becomes clearer when green-finance activity is measured in the preceding year or two years preceding the outcome.

The lagged models are specified as follows: Model 3 uses LNREI lagged by one year, Model 4 uses LNREI lagged by two years, Model 5 uses green-bond issuance lagged by one year, and Model 6 uses green-bond issuance lagged by two years. The same control variables are retained. The coefficients are interpreted as conditional associations rather than causal effects.

Model 3: $GDPG_{it} = \alpha + \beta_1 LNREI_{i,t-1} + \beta_2 INF_{it} + \beta_3 UNEMP_{it} + \beta_4 TO_{it} + \varepsilon_{it}$

Model 4: $GDPG_{it} = \alpha + \beta_1 LNREI_{i,t-2} + \beta_2 INF_{it} + \beta_3 UNEMP_{it} + \beta_4 TO_{it} + \varepsilon_{it}$

Model 5: $GDPG_{it} = \alpha + \beta_1 GB_{i,t-1} + \beta_2 INF_{it} + \beta_3 UNEMP_{it} + \beta_4 TO_{it} + \varepsilon_{it}$

Model 6: $GDPG_{it} = \alpha + \beta_1 GB_{i,t-2} + \beta_2 INF_{it} + \beta_3 UNEMP_{it} + \beta_4 TO_{it} + \varepsilon_{it}$

CHAPTER 4

RESULTS AND ANALYSIS

This chapter reports the empirical results for the seven selected EU countries over 2012–2024. It first presents descriptive statistics and pairwise correlations, followed by stationarity diagnostics, median quantile regression, and pooled OLS estimates. The analysis uses country-year panel data and was conducted in Stata.

The empirical analysis covers seven European Union countries over the thirteen-year period from 2012 to 2024, producing a balanced panel of 91 country-year observations. The analysis was conducted using the supplied country-year dataset. Descriptive statistics and correlations are presented first. The regression analysis then reports pooled OLS estimates and quantile regression results at $q = 0.25$, $q = 0.50$, and $q = 0.75$. Renewable energy investment and green bond issuance are estimated in separate models so that their individual relationships with GDP growth can be examined with the same set of macroeconomic controls.

1. Descriptive Statistics

Table 1 summarises the distribution of the variables. LNREI has a mean of 9.4700 and a standard deviation of 1.7592. Because LNREI is expressed in natural logarithms, its mean is not a direct monetary amount; converting it back to the original scale gives $\exp(9.47)$, approximately 12,959 units of the underlying investment measure. This conversion is meaningful only when considered together with the unit used in the source database. The standard deviation and the range from 5.4424 to 12.0932 indicate substantial cross-country and time variation.

Table 1 presents the descriptive statistics of the variables employed in this study. The statistics provide an overview of the data by reporting the mean, standard deviation, minimum value, and maximum value for each variable. These measures help describe the overall characteristics and variation of the observations collected from the selected European Union countries. The natural logarithm of renewable energy investment (LNREI) has an average value of 9.4700. The standard deviation of 1.7592 indicates meaningful variation across countries and over time. The minimum value of 5.4424 and the maximum value of 12.0932 reveal differences in renewable energy investment and reflect varying levels of commitment to renewable-energy development.

Green bonds (GB) have an average value of 13.9414, while the standard deviation is 17.5039, which is higher than the mean. This indicates considerable variation in green-bond issuance across the sampled countries. The minimum observed value is 0.0740, whereas the maximum is 81.6307. The wide range suggests that green-bond markets have developed unevenly across the selected EU countries, with some countries having well-established markets and others remaining at earlier stages of development. The average GDP growth rate is 1.3631%, with a standard deviation of 2.2384. GDP growth ranges from -7.4406% to 6.9297% , indicating that the sampled countries experienced both economic contractions and periods of expansion during the study period.

Inflation has a mean value of 2.0578% , accompanied by a standard deviation of 2.1204. The minimum value of -0.2079% indicates that some observations experienced slight deflation, while the maximum value of 10.0012% reflects relatively high inflation in certain years. Overall, inflation remained moderate in most observations but varied substantially during periods of economic disruption.

Trade openness (TO) has the highest mean value, at 134.0624, with a standard deviation of 100.9450. The minimum and maximum values of 55.3300 and 412.2000, respectively, indicate substantial variation in the degree of trade integration. Overall, the descriptive statistics show sufficient variation across countries and over time, which is useful for the subsequent panel-data analysis.

Table 1

Descriptive Statistics				
Variables	Mean	Std. Dev	Min	Max
LNREI	9.4700	1.7592	5.4424	12.0932
GB	13.9414	17.5039	0.0740	81.6307
GDP Grwth	1.36311	2.2384	-7.4406	6.9297
Inf	2.0578	2.1204	-0.2079	10.0012
Unemp	6.4270	1.9021	3.0710	10.3540
TO	134.0624	100.9450	55.3300	412.200

Note: LNREI stands for the natural log of renewable energy investment; GB stands for the green bonds; GDP Grwth stands for the gross domestic product growth; Inf stands for inflation; Unemp stands for the unemployment and TO stands for the trade openness.

2. Correlation Matrix

A correlation matrix is used to measure the strength and direction of the linear relationships between the variables. Table 2 reports the pairwise correlation coefficients among the variables used in this study. The purpose of the analysis is to identify the direction and strength of the relationships before conducting regression analysis and to provide an initial indication of whether multicollinearity may be a concern.

The findings show that the relationship between GDP growth and green bonds is positive but extremely weak, with a correlation coefficient of 0.0165. This suggests that changes in green bond issuance are not strongly associated with changes in economic growth at the bivariate level. Likewise, the correlation between GDP growth and inflation is almost zero (-0.0016), indicating that the two variables move independently within the sample. GDP growth has a weak negative association with renewable energy investment (-0.1208) and unemployment (-0.0700). These coefficients imply that higher renewable energy investment and unemployment are associated with slightly lower GDP growth, although the relationships are not strong. In contrast, trade openness has a weak positive relationship with GDP growth (0.1534), suggesting that countries with greater trade integration tend to experience marginally higher economic growth.

Among the explanatory variables, green bonds are positively associated with inflation (0.4076) and renewable energy investment (0.3950). These moderate positive relationships indicate that countries with larger green bond markets also tend to invest more in renewable energy. Green bonds, however, are negatively related to trade openness (-0.0426) and unemployment (-0.3719), although these relationships remain relatively weak. The strongest relationship observed in the matrix is between renewable energy investment and trade openness, with a coefficient of -0.4372 . Even so, the magnitude of this coefficient is well below the commonly accepted threshold of **0.80**, indicating that the relationship is not sufficiently high to create multicollinearity concerns. Inflation and unemployment are also negatively correlated (-0.2949), while trade openness and unemployment display a weak inverse relationship (-0.2782).

Overall, the correlation coefficients are relatively small to moderate in magnitude, and none exceeds the critical value generally used to indicate severe multicollinearity. Therefore, the independent variables appear sufficiently distinct from one another, allowing them to be included

simultaneously in the econometric model. These results suggest that the regression estimates are unlikely to be adversely affected by high intercorrelations among the explanatory variables.

Table 2

Correlation Matrix						
Variables	GDP Grwth	GB	Inf	LNREI	TO	Unemp
GDP Grwth	1					
GB	0.0165	1				
Inf	-0.0016	0.4076	1			
LNREI	-0.1208	0.3950	0.1142	1		
TO	0.1534	-0.0426	0.0951	-0.4372	1	
Unemp	-0.0700	-0.3719	-0.2949	-0.0365	-0.2782	1

Note: LNREI stands for the natural log of renewable energy investment; GB stands for the green bonds; GDP Grwth stands for the gross domestic product growth; Inf stands for inflation; Unemp stands for the unemployment and TO stands for the trade openness.

3. Augmented Dickey-Fuller Test

The Augmented Dickey–Fuller (ADF) test is used to examine whether a time series is stationary or contains a unit root. Non-stationary variables can produce misleading regression relationships if appropriate transformations are not applied. Table 3 presents the ADF results for the variables included in the study. A probability value below 0.05 indicates rejection of the unit-root null hypothesis and is interpreted here as evidence of stationarity.

The results show that LNREI, green bonds, GDP growth, inflation, and unemployment have p-values below 0.05 at level and are therefore classified as $I(0)$. Trade openness is non-stationary at level but becomes stationary after first differencing, with a reported p-value of 0.0020; it is

therefore classified as I(1). The text and table use the same classification. The mixed order of integration is reported as a data property and is not used as the justification for median quantile regression. Overall, the diagnostic suggests that most variables are stationary at level, while trade openness becomes stationary after first differencing. The transformation used for trade openness in the regression analysis should therefore remain consistent with the reported stationarity result.

Table 3

Augmented Dickey-Fuller Test		
Variables	P-Values	Results
LNREI	0.0223	I(0)
GB	0.0015	I(0)
GDP Grwth	0.0004	I(0)
Inf	0.0051	I(0)
Unemp	0.0217	I(0)
TO	0.0020	I(1)

Note: LNREI stands for the natural log of renewable energy investment; GB stands for the green bonds; GDP Grwth stands for the gross domestic product growth; Inf stands for inflation; Unemp stands for the unemployment and TO stands for the trade openness.

4. Regression Analysis

Tables 4 and 5 report quantile regression estimates at $q = 0.25$, $q = 0.50$, and $q = 0.75$. The first specification includes the natural logarithm of renewable energy investment, while the second includes green bond issuance. Inflation, unemployment, and trade openness remain in both specifications. The coefficients describe the relationship with different points of the conditional GDP-growth distribution and should not be interpreted as causal effects.

In the renewable energy investment model, LNREI is positive at all three quantiles. The coefficients are 0.2003 at $q = 0.25$, 0.0727 at $q = 0.50$, and 0.1823 at $q = 0.75$. None of these estimates is statistically significant at conventional levels. The consistent positive sign is in line with the expected direction, but the evidence is not strong enough to conclude that renewable energy investment produced an immediate and measurable change in annual GDP growth within this sample.

Inflation has a negative coefficient throughout the quantile estimates. In the renewable energy model, the coefficient is statistically significant at the lower quantile and at the median, but not at the upper quantile. This pattern suggests that price instability is more closely associated with weak or typical growth conditions than with observations in the upper part of the conditional growth distribution. Unemployment remains statistically insignificant across the reported quantiles.

Table 4

Quantile Regression: Renewable Energy Investment Model						
Variable	q25 Coef.	p-value	q50 Coef.	p-value	q75 Coef.	p-value
LNREI	0.2003	0.5895	0.0727	0.7869	0.1823	0.4314
INF	-0.2601	0.0412**	-0.2192	0.0479**	-0.1422	0.2054
Unemp	0.0211	0.8938	-0.1858	0.1799	-0.0484	0.6981
TO	0.0032	0.6616	0.0020	0.6825	0.0065	0.1194
Constant	-1.6518	0.7314	2.1015	0.5617	0.1956	0.9508

Trade openness is positive in most specifications. Its clearest result appears in the green-bond model at $q = 0.75$, where the coefficient is positive and statistically significant at the 5 percent level. This result indicates that greater trade integration is associated with stronger GDP growth in

the upper part of the conditional distribution, although the same relationship is not statistically clear in the lower and median specifications.

The green-bond coefficient changes across the conditional distribution. It is negative and insignificant at $q = 0.25$, positive but insignificant at $q = 0.50$, and positive with weak statistical evidence at $q = 0.75$. The upper-quantile estimate is significant only at the 10 percent level, so it should be treated as suggestive rather than conclusive. The pattern may reflect the time needed for bond proceeds to move from issuance to project implementation and then to measurable economic activity.

Table 5

Quantile Regression: Green Bond Model						
Variable	q25 Coef.	p-value	q50 Coef.	p-value	q75 Coef.	p-value
GB	-0.0156	0.4028	0.0179	0.1789	0.0255	0.0832*
INF	-0.1100	0.4144	-0.2414	0.0235**	-0.1418	0.2490
Unemp	-0.0583	0.6970	-0.1255	0.2990	-0.1337	0.2735
TO	0.0012	0.6962	0.0031	0.1452	0.0047	0.0272**
Constant	0.9126	0.4817	2.1252	0.0407**	2.5305	0.0189**

Table 6 presents pooled OLS estimates as a benchmark for the average conditional relationship. In Model 1, the LNREI coefficient is 0.0166 with a p-value of 0.9558. In Model 2, the green-bond coefficient is 0.0034 with a p-value of 0.8303. Both estimates are positive but statistically insignificant. The control variables are also statistically insignificant in the pooled specifications, and the R-squared values are approximately 0.025 in both models.

The pooled OLS results are therefore more cautious than the earlier version of the analysis. They do not support a claim that renewable energy investment or green bond issuance had a statistically significant average short-run effect on annual GDP growth during 2012–2024. This does not mean that green finance has no economic value. It means that the available sample does not provide precise evidence of an immediate average effect after controlling for inflation, unemployment, and trade openness.

The limited explanatory power of the pooled models is understandable because annual GDP growth is affected by many factors that are not included in the specification, including fiscal policy, interest rates, external demand, energy prices, productivity shocks, and the exceptional disruption caused by the COVID-19 pandemic. The small sample also limits statistical power.

Comparison of pooled OLS and quantile regression shows why the wider quantile approach is useful. The average effects are weak, while the green-bond coefficient becomes larger and more positive toward the upper conditional quantile. Even so, the evidence remains modest and must be presented with appropriate caution.

The results support a balanced interpretation. Renewable energy investment keeps the expected positive sign but lacks statistical precision. Green bonds show a more favourable relationship under stronger conditional growth conditions, while inflation is most clearly harmful in the lower and middle parts of the distribution. Trade openness appears to complement stronger growth in the upper green-bond model.

These findings do not justify a direct causal statement. Green finance can be influenced by economic growth itself, and omitted institutional or policy factors may affect both financing

activity and output. The results are best understood as conditional associations observed in a small panel of advanced EU economies.

For this reason, the study places greater emphasis on the direction, variation, robustness, and economic interpretation of the coefficients than on isolated significance levels. The following chapter compares the results with the literature and explains their policy meaning.

Table 6

Both Regression Models				
Variable	Model 1 Coef.	p-value	Model 2 Coef.	p-value
LNREI	0.0166	0.9558	—	—
GB	—	—	0.0034	0.8303
INF	-0.0297	0.8078	-0.0372	0.7671
Unemp	-0.0400	0.7945	-0.0339	0.8140
TO	0.0035	0.5183	0.0033	0.1869
Constant	1.0556	0.7935	1.1645	0.3437
R-squared	0.0250	—	0.0255	—

5. Fixed-Effects Robustness Analysis

To address the concern that the weak pooled estimates might be driven by unobserved country characteristics or common time shocks, the two green-finance models were re-estimated using country fixed effects, year fixed effects, and two-way country-and-year fixed effects. The results are reported in Table 7.

The substantive conclusion remains similar to the pooled OLS results: neither renewable energy investment nor green-bond issuance is statistically significant in any of the fixed-effects specifications. Renewable energy investment is statistically insignificant under country fixed effects ($\beta = -1.2264$, $p = 0.2781$), year fixed effects ($\beta = 0.0238$, $p = 0.8958$), and two-way fixed effects ($\beta = 0.7152$, $p = 0.4258$). Green-bond issuance is also statistically insignificant under country fixed effects ($\beta = 0.0054$, $p = 0.7838$), year fixed effects ($\beta = -0.0085$, $p = 0.4268$), and two-way fixed effects ($\beta = -0.0108$, $p = 0.4260$). The change in coefficient signs across specifications indicates that the estimated association is sensitive to whether identification comes primarily from cross-country differences, common annual variation, or within-country variation after both sets of effects are removed. Nevertheless, none of the estimates is statistically precise enough to support a contemporaneous annual growth effect.

The year and two-way models explain a substantially larger share of annual GDP-growth variation than the pooled models, which is consistent with the importance of common macroeconomic shocks during 2012–2024. Overall, the fixed-effects exercise does not overturn the principal findings. Instead, it provides additional evidence that the limited support for the hypotheses is not simply a consequence of persistent country-specific characteristics or common year shocks. The results should therefore be reported as robustly weak short-run evidence rather than as evidence of no long-run economic effect.

Green bond issuance is also statistically insignificant after introducing fixed effects. Its coefficient is 0.0054 with country fixed effects ($p = 0.7838$), -0.0085 with year fixed effects ($p = 0.4268$), and -0.0108 with two-way fixed effects ($p = 0.4260$). The year and two-way models explain a much larger share of annual GDP-growth variation than pooled OLS, which is consistent with the importance of common macroeconomic shocks during 2012–2024. However, controlling for these

shocks does not reveal a statistically significant contemporaneous effect of either green-finance indicator. The fixed-effects exercise therefore strengthens the central interpretation of the thesis: in this selected sample, green finance may have important investment, environmental, and longer-run economic effects, but the annual data do not provide robust evidence of an immediate effect on GDP growth.

Table 7
Fixed-Effects Robustness Analysis

Variable	Country FE Coef.	p-value	Year FE Coef.	p-value	Country + Year FE Coef.	p-value
LNREI	-1.2264	0.2781	0.0238	0.8958	0.7152	0.4258
Green Bonds	0.0054	0.7838	-0.0085	0.4268	-0.0108	0.4260
R-squared (LNREI model)	0.0717	—	0.7315	—	0.7643	—
R-squared (GB model)	0.0588	—	0.7338	—	0.7643	—

6. Lagged-Value Robustness Check

The supervisor recommended an additional estimation using one-year and, where appropriate, two-year lags of the main green-finance variables. This is an appropriate extension because renewable-energy investment and green-bond financing may require time to translate into completed projects, productive capacity, employment, and measurable GDP effects. The thesis already recognises this delayed-transmission mechanism in its discussion of the limitations of contemporaneous annual specifications.

Using the supplied 91 country-year observations, the lagged robustness models were estimated after sorting the panel by country and year. One-year lags reduce the usable sample to 84 observations, while two-year lags reduce it to 77 observations. Table 8 reports the results for lagged renewable-energy investment (LNREI), and Table 9 reports the results for lagged green-bond issuance (GB). The same controls (inflation, unemployment, and trade openness) are retained in all specifications. The estimates are conditional associations and should not be interpreted as causal effects.

Table 8
Lagged Renewable Energy Investment Robustness Analysis

Variable	1-year lag Coef.	p-value	2-year lag Coef.	p-value
Constant	2.9620	0.4983	3.5235	0.4553
LNREI (lagged)	-0.1341	0.6837	-0.1792	0.6186
Inflation	-0.0016	0.9901	0.0034	0.9795
Unemployment	-0.0489	0.7612	-0.0379	0.8237
Trade Openness	0.0007	0.8992	-0.0005	0.9354
Observations	84		77	
R-squared	0.0198		0.0139	

Note: The dependent variable is GDP Growth. All models include inflation, unemployment, and trade openness. No coefficient is statistically significant at the 10% level.

The lagged estimates do not provide evidence of a statistically significant delayed effect within this sample. The coefficient on LNREI is negative and insignificant at both one-year and two-year lags, while lagged green-bond issuance is also negative and statistically insignificant at both horizons. Thus, the additional lagged-value exercise does not overturn the main conclusion: the available annual data do not identify a robust short-run or delayed association between the principal green-finance measures and GDP growth.

Table 9**Lagged Green Bond Issuance Robustness Analysis**

Variable	1-year lag Coef.	p-value	2-year lag Coef.	p-value
Constant	1.7763	0.1544	1.3478	0.2981
Green Bonds (lagged)	-0.0212	0.2344	-0.0044	0.8173
Inflation	0.0544	0.6841	-0.0027	0.9841
Unemployment	-0.0697	0.6383	-0.0089	0.9546
Trade Openness	0.0023	0.3787	0.0022	0.4224
Observations	84		77	
R-squared	0.0353		0.0112	

Note: The dependent variable is GDP Growth. All models include inflation, unemployment, and trade openness. No coefficient is statistically significant at the 10% level.

CHAPTER 5

DISCUSSION

5.1 Overview of the Main Findings

This study set out to examine whether renewable energy investment and green bond issuance are associated with GDP growth in seven advanced European Union economies. The analysis covers a period in which sustainable finance expanded rapidly, while the European economy also faced unusually large shocks. These shocks include the sovereign-debt aftermath, the COVID-19 recession, supply-chain disruption, energy-price volatility, and the inflationary episode that followed. For this reason, the results should be understood in the context of a relatively short and turbulent annual sample.

The descriptive evidence shows substantial variation in renewable energy investment, green bond issuance, trade openness, and GDP growth. Green bond issuance is especially uneven across countries and years. Some observations show only limited issuance, while others reflect well-developed markets and large financing programmes. This dispersion is useful for empirical analysis, but it also means that a small number of large issuers can influence the estimates. The correlation matrix does not indicate severe multicollinearity, although it confirms that the green-finance variables are related to some macroeconomic conditions.

The regression results are more cautious than a simple reading of the positive coefficients might suggest. Renewable energy investment has a positive coefficient at the lower, median, and upper conditional quantiles, yet none of the estimates is statistically significant. Green bond issuance changes from a negative coefficient at the lower quantile to positive coefficients at the median and upper quantiles. The upper-quantile coefficient provides weak evidence at the 10 percent level.

Pooled OLS produces small positive but insignificant coefficients for both green-finance indicators. Taken together, the evidence suggests potential rather than a uniform or immediate growth effect.

The fixed-effects robustness analysis reinforces this cautious interpretation. After controlling separately for country-specific characteristics, common year shocks, and both dimensions together, neither renewable energy investment nor green bond issuance becomes statistically significant. This is an important result because it indicates that the weak pooled relationship is not simply an artefact of persistent differences between the seven countries or of common events such as the pandemic and the European inflation and energy shocks. The substantive conclusion is therefore stable across alternative panel specifications.

5.2 Renewable Energy Investment and Economic Growth

The positive sign of renewable energy investment across all three quantiles is consistent with the argument that spending on renewable capacity can contribute to economic activity. Investment in solar, wind, hydropower, grids, storage, and related infrastructure can increase demand for construction, engineering, equipment, finance, and professional services. It may also reduce exposure to imported fossil fuels and support technological learning. These channels are consistent with endogenous growth theory, which links investment, innovation, and knowledge accumulation to long-run productivity.

However, the absence of statistical significance is also economically plausible. Renewable energy projects usually have long planning and construction periods. Expenditure recorded in one year may not produce additional output in the same year, and some projects replace existing capacity rather than expand total productive capacity. In advanced EU economies, where energy systems and infrastructure are already mature, the short-run marginal effect on aggregate GDP growth may

be small compared with larger forces such as external demand, interest rates, fiscal policy, and productivity developments.

The result also reflects the way the variable is measured. The supplied series records aggregate renewable energy investment and does not provide a consistent division between public and private sources for all countries and years. It also does not distinguish between technologies, project stages, or the domestic content of investment. A country may record a large investment programme while importing much of the equipment, which can reduce the immediate domestic value-added effect. Conversely, smaller investment may generate stronger local effects when domestic supply chains are well developed.

The findings therefore do not reject the economic importance of renewable energy investment. They show that its annual relationship with GDP growth is difficult to identify precisely in a small multi-country sample. The effect may be delayed, technology-specific, or dependent on institutional and industrial conditions. Future work with longer time series, lagged investment variables, and sector-level output could examine these channels more directly.

5.3 Green Bonds and Economic Growth

Green bonds are a financing instrument rather than a direct measure of completed green investment. Their proceeds can support renewable energy, clean transport, energy-efficient buildings, waste management, and climate-resilient infrastructure. The economic effect depends on whether issuance finances additional projects, refinances existing assets, or replaces other sources of funding. This distinction helps explain why a rise in issuance does not necessarily lead to an immediate rise in GDP growth.

The negative and insignificant coefficient at the lower quantile may reflect weak economic conditions in which governments and firms issue bonds while growth remains subdued. Issuance

can increase during periods of policy support or refinancing need, even when the wider economy is under pressure. At the median, the coefficient becomes positive but remains imprecise. At the upper quantile, the coefficient is larger and weakly significant, which suggests that green bond activity may be more closely associated with growth when general economic conditions are already favourable.

This interpretation should remain cautious. The upper-quantile result is significant only at the 10 percent level and does not establish causality. Stronger growth can itself support bond issuance by improving investor confidence, fiscal capacity, and corporate financing conditions. The observed relationship may therefore run in both directions. It may also reflect omitted factors such as institutional quality, financial-market depth, the credibility of green standards, and the quality of project selection.

The result is nevertheless relevant for policy. It suggests that the economic contribution of green bonds depends less on the label attached to the security and more on the use of proceeds, additionality, monitoring, and implementation. Clear standards, external review, transparent reporting, and reliable impact measurement can strengthen the link between funds raised and real economic activity.

5.4 Control Variables and the Macroeconomic Environment

Inflation has a negative coefficient in all quantile specifications and is statistically significant in the lower and median renewable-investment models and in the median green-bond model. Higher inflation can reduce real household income, raise construction and financing costs, and create uncertainty about future prices. These effects can delay investment and weaken demand. The stronger negative association in the lower and middle parts of the conditional growth distribution

suggests that price instability is especially damaging when economic performance is already weak or moderate.

Unemployment generally has a negative but insignificant coefficient. The lack of statistical precision may reflect the relatively strong labour-market institutions and social-protection systems of the selected countries. It may also arise because annual GDP growth and unemployment adjust at different speeds. Labour-market effects can lag behind output changes, while temporary labour-hoarding arrangements can weaken the immediate relationship during recessions.

Trade openness is positive in most specifications and becomes statistically significant in the upper green-bond model. Open economies can benefit from larger markets, access to imported technology, specialised supply chains, and foreign investment. At the same time, openness can increase exposure to external shocks. The positive upper-quantile result suggests that trade integration may reinforce growth when domestic and international conditions are supportive.

5.5 Comparison with Previous Studies

The positive but statistically weak renewable-investment results are consistent with studies that describe the energy-growth relationship as heterogeneous across countries and technologies. Earlier research has found positive long-run effects in several panels, but it has also shown that the timing and magnitude of the effect depend on policy stability, technological maturity, and the structure of the economy. The present findings add to this mixed evidence by showing that a positive direction can coexist with limited short-run statistical precision in advanced EU economies.

The green-bond results also fit the wider literature. Research on green bonds often reports financing, signalling, and environmental benefits, while the direct macroeconomic effect is less clear. A bond can lower financing costs or improve access to capital without producing an

immediate change in national output. The movement from a negative lower-quantile coefficient to a positive upper-quantile coefficient supports the view that market and economic conditions matter for the transmission of green finance.

The results differ from studies that report strong and uniform positive effects of green finance on growth. This difference may be due to the sample, the use of annual GDP growth rather than a long-run output measure, and the separation of renewable investment and green bonds into two models. It may also reflect the advanced stage of development of the selected countries. In mature economies, the contribution of an additional unit of investment to annual growth may be smaller than in economies with large infrastructure gaps.

5.6 Policy Implications

The first policy implication is that the quantity of green finance should not be treated as the only measure of success. Governments and financial institutions should also examine project quality, implementation speed, domestic value added, environmental additionality, and long-term operating performance. A larger volume of labelled finance will have limited economic value if projects are delayed, poorly selected, or mainly used to refinance activities that would have taken place without the green label.

Second, credible standards remain essential. The EU Taxonomy and sustainability-disclosure rules can improve comparability, but their practical value depends on consistent definitions, reliable data, and effective enforcement. Independent review and post-issuance reporting can reduce greenwashing and improve investor confidence. Better reporting would also make future empirical research more accurate by allowing researchers to distinguish between issuance, allocation, and completed investment.

Third, renewable energy policy should support domestic capabilities alongside project finance. Training, research and development, grid infrastructure, storage, permitting reform, and local supply chains can increase the share of investment that becomes domestic output and employment. Financing alone cannot remove technical, administrative, or labour-market bottlenecks.

Fourth, macroeconomic stability matters. The negative inflation coefficients indicate that high and uncertain prices can weaken the environment in which green projects are planned and financed. Stable policy frameworks, predictable regulation, and access to long-term finance can reduce the risk premium attached to capital-intensive projects.

Fifth, policy should recognise differences between countries. Germany, France, the Netherlands, Sweden, Denmark, Luxembourg, and Finland differ in market size, energy structure, financial depth, and trade exposure. A common EU framework can provide standards and coordination, but national policies should reflect local industrial capacity, grid needs, and financing conditions.

Finally, green finance should be evaluated over an appropriate time horizon. The weak annual results do not rule out larger medium- or long-run effects. Public authorities should use multi-year impact assessment that follows projects from financing approval through construction and operation. This would provide a clearer picture of output, employment, energy-security, and emissions effects.

5.7 Limitations and Directions for Future Research

The study has several limitations. The sample contains seven advanced EU economies and 91 annual observations. The countries were selected purposively because they display comparatively strong or visible green-finance and renewable-energy activity and provide consistent data over the common period. This focused design is useful for studying economies where green-finance mechanisms are already meaningful, but it is not intended to represent the full institutional and

economic diversity of all EU member states. The relatively small number of countries also limits statistical power and external validity. A broader EU sample would be valuable where fully comparable annual green-bond and renewable-investment data can be assembled.

The analysis includes pooled OLS, quantile regression, and additional country, year, and two-way fixed-effects robustness specifications. The fixed-effects results are substantively similar and do not produce statistically significant coefficients for the two green-finance indicators. Nevertheless, GDP growth is influenced by many time-varying factors that are not included in the model, and fixed effects cannot remove all forms of omitted-variable bias or reverse causality. The study period also contains the exceptional COVID-19 shock and the subsequent inflation and energy-price disturbances, which strongly affect annual growth dynamics.

Measurement is another limitation. Renewable energy investment may include both public and private financing, while the green-bond variable measures issuance rather than verified project expenditure. The available data do not consistently identify the technology, project stage, issuer type, currency treatment, or share of proceeds allocated within the same year. These issues make the estimated coefficients broader indicators rather than precise measures of project-level impact.

Future research should extend the time period and, where comparable data are available, include a broader range of EU countries. It should also test lagged relationships because infrastructure investment and the use of green-bond proceeds may affect output only after several years. Dynamic panel methods, panel quantile models, and alternative inference procedures could provide additional robustness. Researchers could separate sovereign, corporate, and financial-sector green bonds and distinguish between solar, wind, grid, storage, and other forms of renewable investment. A comparison of pre- and post-COVID periods would also be valuable.

CHAPTER 6

CONCLUSIONS

This thesis examined the relationship between green finance and economic growth in seven selected European Union economies over the period 2012–2024. The analysis focused on two distinct dimensions of green finance: renewable energy investment, which represents the deployment of capital into renewable-energy projects and productive assets, and green bond issuance, which represents a market-based financing mechanism through which capital can be mobilised for eligible environmental projects. GDP growth was used as the measure of annual economic performance, while inflation, unemployment, and trade openness were included as macroeconomic controls. The central objective was to determine whether higher levels of renewable-energy investment and green-bond issuance are associated with stronger annual GDP growth in economies where green-finance activity is already comparatively visible and developed.

The sample was deliberately focused rather than designed as a representative cross-section of all EU member states. Germany, France, the Netherlands, Sweden, Denmark, Luxembourg, and Finland were selected because they combine mature or developing sustainable-finance markets, substantial renewable-energy or green-finance activity, established climate-policy frameworks, and consistent annual data across the variables required for the empirical analysis. This design allowed the thesis to study the relationship in economies where green finance is economically meaningful instead of mixing observations with very different levels of market development and incomplete data coverage. At the same time, this purposive selection means that the results should be interpreted as evidence for the selected advanced EU economies rather than as an estimate for the entire European Union.

The empirical findings provide limited support for the two research hypotheses when the outcome is measured as contemporaneous annual GDP growth. Renewable energy investment has a positive coefficient at the 25th, 50th, and 75th conditional quantiles, which is consistent with the theoretical expectation that investment in renewable capacity can support economic activity. However, none of these coefficients is statistically significant. The pooled OLS estimate is also very small and statistically insignificant. The results therefore do not provide sufficient statistical evidence to accept the proposition that a rise in renewable energy investment produces an immediate increase in annual GDP growth within the sample period. This does not imply that renewable investment has no economic value. Rather, it suggests that its contribution may operate through longer construction cycles, technological learning, energy security, lower import dependence, productivity improvements, and sectoral changes that are not captured fully by same-year aggregate GDP growth.

The findings for green bonds are similarly cautious. Green-bond issuance is negative and insignificant at the lower conditional quantile, becomes positive at the median, and is positive with only weak statistical evidence at the upper quantile. Pooled OLS does not identify a statistically significant average relationship. The changing coefficient across the growth distribution suggests that the economic association of green-bond activity may depend on the wider macroeconomic environment. A bond issuance is a financing event rather than proof that new productive capacity has already been completed. Proceeds may finance projects over several years, refinance existing assets, or be allocated across different sectors. For this reason, the absence of a strong same-year GDP effect is economically plausible and should not be interpreted as evidence that green bonds are ineffective as financing instruments.

An important extension requested in the review of this thesis was the introduction of country and year fixed effects. These robustness models were estimated to test whether the pooled results were being driven by persistent differences between countries or by common shocks affecting all countries in particular years. The results remain substantively similar. Renewable energy investment is statistically insignificant under country fixed effects, year fixed effects, and two-way country-and-year fixed effects. Green-bond issuance is also insignificant in all three specifications. The year and two-way models explain a substantially larger proportion of annual GDP-growth variation, highlighting the importance of common macroeconomic events during 2012–2024. Nevertheless, the inclusion of fixed effects does not reveal a robust contemporaneous green-finance coefficient. This consistency across pooled and fixed-effects models strengthens the conclusion that the weak short-run relationship is not solely a consequence of omitted time-invariant country characteristics or common year shocks.

The results for the control variables provide additional context. Inflation is generally negatively associated with GDP growth in the quantile models and is statistically significant in several lower and median specifications. This pattern is consistent with the view that price instability can weaken household purchasing power, increase financing and construction costs, and create uncertainty for investment decisions. Trade openness is positive in most specifications and becomes statistically significant in the upper green-bond quantile model, suggesting that integration with international markets may reinforce growth under relatively favourable conditions. Unemployment is generally insignificant, which may reflect adjustment lags between output and labour-market outcomes as well as the institutional characteristics of the selected European economies.

Taken together, the evidence leads to a more nuanced interpretation of the green-finance-growth relationship than a simple positive or negative conclusion. Green finance is designed primarily to

redirect capital toward environmentally sustainable projects and to facilitate the transition to a low-carbon economy. Many of its benefits are therefore expected to arise through channels such as cleaner energy capacity, lower environmental risk, technological innovation, energy independence, improved infrastructure, and reduced exposure to fossil-fuel price volatility. These benefits can contribute to long-run productive capacity without necessarily generating a statistically detectable change in annual GDP growth in the same year that financing or investment is recorded. The findings therefore support the theoretical possibility of a positive long-run contribution while showing that short-run macroeconomic effects are difficult to identify precisely in the available data.

The study also has practical implications for European policy. The volume of green finance should not be treated as the sole indicator of success. Policymakers and financial institutions should pay equal attention to the quality of funded projects, additionality, implementation speed, domestic value creation, technological spillovers, and the transparency of the use of proceeds. Strong disclosure standards, credible green classifications, independent verification, and post-issuance reporting can improve the connection between capital raised and real economic activity. Renewable-energy finance should also be accompanied by investment in electricity grids, storage, skills, research and development, permitting capacity, and domestic supply chains. These complementary conditions determine how effectively financial resources translate into productive investment.

The findings further suggest that the timing of evaluation matters. Renewable infrastructure normally requires planning, approval, financing, construction, connection, and operational phases before its full economic effect is visible. Green-bond proceeds may also be spent over more than one fiscal year. A model based on contemporaneous annual values can therefore underestimate

effects that emerge with a lag. Future empirical work should examine one-year, two-year, and longer lag structures and should distinguish new investment from refinancing where data permit. Longer panels would also reduce the influence of exceptional events such as the COVID-19 recession and the subsequent European energy and inflation shocks.

The lagged-value robustness exercise provides an empirical check of this timing argument. Although theory suggests that renewable-energy projects and green-bond-financed activities may take time to affect productive capacity, the one-year and two-year pooled specifications estimated here do not show statistically significant effects. LNREI remains insignificant at both lag horizons, and green-bond issuance is likewise insignificant. These findings should be interpreted cautiously because the lagged models use fewer observations and the sample covers only seven countries over 2012–2024. Nevertheless, the results indicate that the weak contemporaneous relationships are not replaced by a clear delayed effect within the tested horizons.

Several limitations should therefore be recognised when interpreting the thesis. The number of countries is small, although the sample was intentionally chosen to focus on economies with meaningful green-finance activity and consistent data. The variables are broad national aggregates and cannot fully identify differences in project quality, issuer type, technology, public versus private financing, or domestic versus imported investment content. Annual GDP growth is also influenced by fiscal policy, monetary conditions, external demand, productivity, demographic developments, and geopolitical shocks. Country and year fixed effects address some forms of unobserved heterogeneity, but they cannot establish causality or eliminate every source of endogeneity. Reverse causality is also possible because stronger economic conditions can themselves increase investment capacity and facilitate bond issuance.

For future research, the strongest extension would be to combine a longer time horizon with broader country coverage once comparable green-finance data are available. A larger and more heterogeneous EU panel could improve statistical power and make it possible to test whether effects differ between advanced green-finance markets and countries at earlier stages of market development. Dynamic panel techniques, lagged explanatory variables, panel quantile methods, and sector-level analysis could provide a clearer account of the transmission mechanism. Separating sovereign and corporate green bonds, and distinguishing renewable investment by technology, would also help determine which forms of finance are most closely connected with productive outcomes.

The lagged robustness results provide an additional qualification to this conclusion: neither one-year nor two-year lags of renewable-energy investment or green-bond issuance produce a statistically significant pooled association with GDP growth in the available sample.

The final conclusion of this thesis is therefore not that green finance fails to contribute to economic development. The evidence shows instead that its relationship with annual GDP growth is neither automatic nor immediate. In the selected EU economies, renewable-energy investment retains a generally positive direction in the quantile analysis, while green bonds become more favourable under stronger conditional growth conditions, but these relationships are not robustly significant across the principal annual specifications. The fixed-effects results confirm the same broad conclusion. Green finance should consequently be evaluated as part of a longer-term structural transition in which financing quality, institutional credibility, project implementation, technological capacity, and macroeconomic stability determine whether environmental investment is eventually translated into higher productivity and sustainable economic growth.

This thesis examined the relationship between green finance and economic growth in seven European Union countries from 2012 to 2024. The wider quantile analysis shows that renewable energy investment has a positive but statistically insignificant association with GDP growth across the lower, median, and upper conditional quantiles. Green bond issuance is negative at the lower quantile, positive at the median, and more strongly positive at the upper quantile, where the evidence is weak but suggestive. Pooled OLS estimates remain small and statistically insignificant.

The main conclusion is that green finance should not be expected to produce an automatic or immediate increase in annual GDP growth. Its economic contribution depends on the quality and timing of projects, the credibility of financial instruments, institutional capacity, macroeconomic stability, and the wider conditions in which investment takes place. Green finance remains important for the transition to a low-carbon economy, but its success should be assessed through real project outcomes as well as financing volumes.

The study therefore supports a careful policy position. The EU should continue to develop credible green-finance markets and renewable energy investment, while improving disclosure, project monitoring, implementation capacity, and long-term evaluation. Stronger data and longer time horizons will be needed to measure the full economic effects of the green transition.

APPENDIX A: REPRODUCIBLE STATA COMMANDS

```
import excel "data.xlsx", sheet("full data") firstrow clear

qreg GDPGrowth LNREI Inflation Unemployment TradeOpenness, quantile(.25)
qreg GDPGrowth LNREI Inflation Unemployment TradeOpenness, quantile(.50)
qreg GDPGrowth LNREI Inflation Unemployment TradeOpenness, quantile(.75)
qreg GDPGrowth GreenBonds Inflation Unemployment TradeOpenness, quantile(.25)
qreg GDPGrowth GreenBonds Inflation Unemployment TradeOpenness, quantile(.50)
qreg GDPGrowth GreenBonds Inflation Unemployment TradeOpenness, quantile(.75)

regress GDPGrowth LNREI Inflation Unemployment TradeOpenness
regress GDPGrowth GreenBonds Inflation Unemployment TradeOpenness

encode Countries, gen(country_id)

xtset country_id Years

xtreg GDPGrowth LNREI Inflation Unemployment TradeOpenness, fe

xtreg GDPGrowth GreenBonds Inflation Unemployment TradeOpenness, fe

regress GDPGrowth LNREI Inflation Unemployment TradeOpenness i.Years
regress GDPGrowth GreenBonds Inflation Unemployment TradeOpenness i.Years

xtreg GDPGrowth LNREI Inflation Unemployment TradeOpenness i.Years, fe
xtreg GDPGrowth GreenBonds Inflation Unemployment TradeOpenness i.Years, fe

* Lagged-variable robustness commands (one- and two-year lags)

sort country_id Years
xtset country_id Years

gen L1_LNREI = L1.LNREI
gen L2_LNREI = L2.LNREI
gen L1_GB = L1.GreenBonds
gen L2_GB = L2.GreenBonds
```

```

regress GDPGrowth L1_LNREI Inflation Unemployment TradeOpenness
regress GDPGrowth L2_LNREI Inflation Unemployment TradeOpenness
regress GDPGrowth L1_GB Inflation Unemployment TradeOpenness
regress GDPGrowth L2_GB Inflation Unemployment TradeOpenness

qreg GDPGrowth L1_LNREI Inflation Unemployment TradeOpenness, quantile(.25)
qreg GDPGrowth L1_LNREI Inflation Unemployment TradeOpenness, quantile(.50)
qreg GDPGrowth L1_LNREI Inflation Unemployment TradeOpenness, quantile(.75)
qreg GDPGrowth L2_LNREI Inflation Unemployment TradeOpenness, quantile(.25)
qreg GDPGrowth L2_LNREI Inflation Unemployment TradeOpenness, quantile(.50)
qreg GDPGrowth L2_LNREI Inflation Unemployment TradeOpenness, quantile(.75)
qreg GDPGrowth L1_GB Inflation Unemployment TradeOpenness, quantile(.25)
qreg GDPGrowth L1_GB Inflation Unemployment TradeOpenness, quantile(.50)
qreg GDPGrowth L1_GB Inflation Unemployment TradeOpenness, quantile(.75)
qreg GDPGrowth L2_GB Inflation Unemployment TradeOpenness, quantile(.25)
qreg GDPGrowth L2_GB Inflation Unemployment TradeOpenness, quantile(.50)
qreg GDPGrowth L2_GB Inflation Unemployment TradeOpenness, quantile(.75)

```

The exact variable names may need to be adjusted after import, depending on how Stata reads the column headings. The same cleaned 91-observation sample and the same standard-error settings must be used to reproduce the reported values. The fixed-effects commands above reproduce the country, year, and two-way robustness checks reported in Table 7.

REFERENCES

- Adekoya, O. B., Oliyide, J. A., Asl, M. G., & Jalalifar, S. (2021). Financing the green projects: Market efficiency and volatility persistence of green versus conventional bonds, and the comparative effects of health and financial crises. *International Review of Financial Analysis*, 78, 101954.
- Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, 124(1), 1–51. <https://doi.org/10.1086/684581>
- Aghion, P., Dewatripont, M., & Rey, P. (1998). Competition, financial discipline and growth. *The Review of Economic Studies*, 65(3), 165–186. <https://doi.org/10.1111/1467-937X.00049>
- Aghion, P., Hepburn, C., Teytelboym, A., & Zenghelis, D. (2009). Path dependence, innovation, and the economics of climate change. Grantham Research Institute on Climate Change and the Environment. <https://doi.org/10.1007/978-3-319-73048-8>
- Agliardi, E., & Agliardi, R. (2019). Financing environmentally sustainable projects with green bonds. *Energy Economics*, 84, 104512. <https://doi.org/10.1016/j.eneco.2019.104512>
- Akhmat, G., & Zaman, K. (2013). Nuclear energy consumption, commercial energy consumption and economic growth in South Asia: Bootstrap panel causality test. *Renewable and Sustainable Energy Reviews*, 25, 552–559.
- Akhmat, G., Zaman, K., & Shukui, T. (2013). Balance of payment prospects and policy implications in light of energy sources in Pakistan. *Energy Education Science and Technology Part B: Social and Educational Studies*, 5(4), 655–686.

- Akomea-Frimpong, I., Zhang, Y., & Sun, L. (2022). Financing sustainability: Global challenges and opportunities. *Journal of Sustainable Finance*.
<https://doi.org/10.1080/20430795.2022.2031234>
- Al Mamun, M., Boubaker, S., & Nguyen, D. K. (2022). Green finance and decarbonization: Evidence from around the world. *Finance Research Letters*, 46, 102807.
- Al Mamun, M., Sohag, K., Mia, M., & Shahbaz, M. (2018). Environmental spending and economic growth in developing economies. *Energy Economics*, 75, 513–524.
<https://doi.org/10.1016/j.eneco.2018.09.014>
- Alemzero DA, Iqbal N, Iqbal S, Mohsin M, Chukwuma NJ, Shah BA (2021) Assessing the perceived impact of exploration and production of hydrocarbons on households perspective of environmental regulation in Ghana. *Environ Sci Pollut Res* 28(5):5359–5371
- Alvarez, M., & Rossi, L. (2024). Measuring green finance: Challenges of taxonomy and disclosure in Europe. *Journal of Sustainable Finance & Investment*, 14(2), 115–132.
<https://doi.org/10.1080/20430795.2023.2281130>
- Anh Tu, C., Chien, F., Hussein, M. A., Ramli MM, Y., Psi MM, M. S. S., Iqbal, S., & Bilal, A. R. (2021). Estimating role of green financing on energy security, economic and environmental integration of BRI member countries. *The Singapore Economic Review*
- Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, 38, 656–660.
- Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, 34, 733–738.

- Apergis, N., & Payne, J. E. (2012). The electricity consumption-growth nexus: Renewable versus non-renewable electricity in Central America. *Energy Sources Part B: Economics, Planning, and Policy*, 7, 423–431.
- Apergis, N., & Payne, J. E. (2014). Renewable energy, output, CO₂ emissions and fossil fuel prices. *Energy Economics*, 42, 227–232.
- Arifin, J., & Syahrudin, N. (2011). Causality relationship between renewable and non-renewable energy consumption and GDP in Indonesia. *Economics and Finance in Indonesia*, 59, 1–18.
- Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of U.S. green bonds. *Journal of Financial Economics*, 134(2), 323–343. <https://doi.org/10.1016/j.jfineco.2021.01.010>
- Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of U.S. green bonds. NBER Working Paper No. 25194. <https://doi.org/10.3386/w25194>
- Banga, J. (2019). The green bond market: A potential source of climate finance for developing countries. *Journal of Sustainable Finance & Investment*, 9(1), 17–32. <https://doi.org/10.1080/20430795.2018.1498611>
- Barro, R. J. (1995). Inflation and economic growth. *Bank of England Quarterly Bulletin*, 35(2), 166–176.
- Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy*, 162, 733–741. <https://doi.org/10.1016/j.apenergy.2015.10.104>

- Bhattacharyya, R. (2022). Green finance for energy transition, climate action and sustainable development: Overview of concepts, applications, implementation and challenges. *Green Finance*, 4(1), 1–35.
- Blanchard, O. (2017). *Macroeconomics*. Pearson Education.
- Browne S (1995) Optimal investment policies for a firm with a random risk process: exponential utility and minimizing the probability of ruin. *Math Oper Res* 20(4):937–958
- Campiglio, E. (2016). Beyond carbon pricing: The role of financial regulation in climate change mitigation. *Ecological Economics*, 121, 343–353. <https://doi.org/10.1016/j.ecolecon.2015.03.026>
- Chang, T. H., et al. (2017). Renewable energy consumption and economic growth across OECD countries. *Energy Policy*, 100, 107–115. <https://doi.org/10.1016/j.enpol.2016.10.018>
- Dahhou, B., et al. (2024). Renewable energy and employment creation. *Journal of Cleaner Production*, 389, 136–145.
- Dahhou, N., Bahetta, S., Bouyghrissi, S., & Kharbouch, O. (2024). Renewable energy, green finance, and economic growth in Morocco: Evidence from an ARDL approach. *International Journal of Energy Economics and Policy*. <https://doi.org/10.32479/ijeep.18522>
- Desalegn, G., & Tangl, A. (2022). Enhancing green finance for inclusive green growth: A systematic approach. *Sustainability*, 14(12), 7416.
- Devine, A., & McCollum, M. (2021). Advancing energy efficiency through green bond policies. Available at SSRN 3856312.

- Eid, A. G., & Mrabet, Z. (2024). Assessing the impact of energy R&D on green growth in OECD countries: A CS-ARDL analysis. *Environmental Economics and Policy Studies*. <https://doi.org/10.1007/s10018-024-00413-4>
- Eid, F., & Mrabet, Z. (2024). Green finance and sustainable development. *Sustainable Development*, 32(1), 85–98.
- European Central Bank. (2025). Green investment needs in the EU and their funding. ECB Economic Bulletin, Issue 1/2025.
- European Commission. (2024). EU taxonomy for sustainable activities: Progress and challenges. Brussels: European Commission.
- European Environment Agency. (2024). Financing the transition towards sustainable activities. Brussels: EEA.
- European Parliament. (2025). Green and sustainable finance briefing. Brussels: European Parliament.
- Ewing, B. T., Sari, R., & Soytas, U. (2007). Disaggregate energy consumption and industrial output in the United States. *Energy Policy*, 35, 1274–1281.
- Flammer, C. (2021). Corporate green bonds. *J Financ Econ*
- Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, 142(2), 499–516. <https://doi.org/10.1016/j.jfineco.2021.05.009>
- Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, 142(2), 499–516. <https://doi.org/10.1016/j.jfineco.2021.01.010>

Frankel, J. A., & Romer, D. (1999). Does trade cause growth? *American Economic Review*, 89(3), 379–399. <https://doi.org/10.1257/aer.89.3.379>

Hu, D., & Gan, C. (2025). Green finance development and its origin, motives, and barriers: An exploratory study. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-025-03012-1>

Huang, Y., Chen, C., Lei, L., & Zhang, Y. (2022). Impacts of green finance on green innovation: A spatial and nonlinear perspective. *Journal of Cleaner Production*, 365, 132548.

International Energy Agency. (2021). World energy employment report. <https://www.iea.org>

International Labour Organization. (2021). World employment and social outlook: Data definitions and methodology.

International Renewable Energy Agency. (2022). Renewable energy and jobs – Annual review 2022. <https://www.irena.org/publications>

International Renewable Energy Agency. (2023). Renewable capacity statistics 2023. <https://www.irena.org>

Iqbal S, Bilal AR, Nurunnabi M, Iqbal W, Alfakhri Y, Iqbal N (2021a) It is time to control the worst: testing COVID-19 outbreak, energy consumption and CO₂ emission. *Environ Sci Pollut Res* 28(15):19008–19020

Iqbal, S., Taghizadeh-Hesary, F., Mohsin, M., & Iqbal, W. (2021). Assessing the role of the green finance index in environmental pollution reduction. *Stud Appl Econ* 39(3).

- Khan, M. A., Khan, M. Z., Zaman, K., & Arif, M. (2014). Global estimates of energy-growth nexus: Application of seemingly unrelated regressions. *Renewable and Sustainable Energy Reviews*, 29, 63–71.
- Khan, M. A., Riaz, H., Ahmed, M., & Saeed, A. (2022). Does green finance really deliver what is expected? An empirical perspective. *Borsa Istanbul Review*, 22(3), 586–593.
- Khan, M., Baloch, A., & Li, J. (2025). Green finance and renewable energy adoption: Evidence from advanced economies. *Energy Economics*, 126, 106789. <https://doi.org/10.1016/j.eneco.2024.106789>
- Khoso, I. A., Shawkat, S., & Ahmed, H. (2025). Green finance and economic growth: A sustainable development perspective. *International Journal of Social Sciences Bulletin*, 3(12), 843–861. <https://doi.org/10.5281/zenodo.18129779>
- Krastev, B., & Krasteva Hristova, R. (2024). Challenges and trends in green finance in the context of sustainable development. *Journal of Risk and Financial Management*, 17(7), 301. <https://doi.org/10.3390/jrfm17070301>
- Krogstrup, S., & Oman, W. (2019). Macroeconomic and financial policies for climate change mitigation: A review of the literature. IMF Working Paper.
- Latif, B., Ong, T. S., Meero, A., Abdul Rahman, A. A., & Ali, M. (2022). Employee-perceived corporate social responsibility (CSR) and employee pro-environmental behavior (PEB): The moderating role of CSR skepticism and CSR authenticity. *Sustainability*, 14(3), 1380.
- Le TH, Chang Y, Taghizadeh-Hesary F, Yoshino N (2019) Energy insecurity in Asia: a multi-dimensional analysis. *Econ Model* 83:84–95

- Li, W., Chien, F., Hsu, C. C., Zhang, Y., Nawaz, M. A., Iqbal, S., & Mohsin, M. (2021). Nexus between energy poverty and energy efficiency: estimating the long-run dynamics. *Resour Policy*, 72, 102063.
- Lindenberg, N. (2014). Definition of green finance. Green Finance Network. Retrieved from https://collaboration.worldbank.org/content/sites/collaboration-for-development/en/groups/green-finance-community-of-practice/documents.entry.html/2018/08/25/definition_of_green-mp3F.html
- Liu, M. (2022). The driving forces of green bond market volatility and the response of the market to the COVID-19 pandemic. *Economic Analysis and Policy*, 75, 288–309.
- Lu, Y., Ahmad, S., Noureen, S., & Salman, M. (2025). Green growth and sustainable energy transitions: Evaluating the critical role of technology, resource efficiency, and innovation in Europe's low-carbon future. *Humanities and Social Sciences Communications*, 12(1527). <https://doi.org/10.1057/s41599-025-01527-x>
- Magnani, N., & Vaona, A. (2011). Regional spillover effects of renewable energy generation in Italy (Working Paper No. 12). Department of Economics, University of Verona.
- Maltais, A., & Nykvist, B. (2020). Understanding the role of green bonds in advancing sustainability. *J Sustain Finance Invest*, 1–20.
- Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, 107(2), 407–437. <https://doi.org/10.2307/2118477>
- Marques, A. C., & Fuinhas, J. A. (2012). Renewable energy and economic growth: Evidence from European panel data. *Energy Policy*, 38, 690–695. <https://doi.org/10.1016/j.enpol.2009.10.027>

Mavlutova, I., et al. (2023). Green bonds and economic growth in Europe. *Journal of Environmental Management*, 330, 117–125.

Mavlutova, I., Spilbergs, A., Verdenhofs, A., Kuzmina, J., Arefjevs, I., & Natrins, A. (2023). The role of green finance in fostering sustainability of the economy and renewable energy supply. *Energies*, 16(23), 7712. <https://doi.org/10.3390/en16237712>

Mertzanis, C., Basu, K., & Stephanou, C. (2019). ESG macroeconomic finance and performance. *International Review of Financial Analysis*, 63, 244–256. <https://doi.org/10.1016/j.irfa.2019.03.006>

Mumtaz, R., Zaman, K., Sajjad, F., Lodhi, M., Irfan, S., Khan, M., et al. (2014). Modeling the causal relationship between energy and growth factors: Journey towards sustainable development. *Renewable Energy*, 63, 353–365.

Nenonen, S., Koski, A., Lassila, A. P., & Lehtikoinen, S. (2019, October). Towards low carbon economy—green bond and asset development. In *IOP Conference Series: Earth Environ Sci* (Vol. 352, No. 1, p. 012028). IOP Publishing.

Ng, A. W. (2018). From sustainability accounting to a green financing system: Institutional legitimacy and market heterogeneity in a global financial centre. *Journal of Cleaner Production*, 195, 585–592.

Ohler, A., & Fetters, I. (2014). The causal relationship between renewable electricity generation and GDP growth: A study of energy sources. *Energy Economics*, 43, 125–139. <https://doi.org/10.1016/j.eneco.2014.02.009>

Organisation for Economic Co-operation and Development. (2022). Financing climate action in times of crisis: Fiscal and financial instruments for a low-carbon recovery. OECD Green Finance and Investment Reviews. <https://www.oecd.org>

Organisation for Economic Co-operation and Development. (2024). Financing green growth in Europe: Policy frameworks and investment trends. OECD Publishing.

Ozturk, I., & Bilgili, F. (2015). Economic growth and biomass energy consumption: Empirical evidence from BRICS countries. *Renewable and Sustainable Energy Reviews*, 44, 110–117. <https://doi.org/10.1016/j.rser.2014.12.006>

Payne, J. E. (2011). On biomass energy consumption and real output in the US. *Energy Sources Part B: Economics, Planning, and Policy*, 6, 47–52.

Peng, W., & Xiong, L. (2022). Managing financing costs and fostering green transition: The role of green financial policy in China. *Economic Analysis and Policy*, 76, 820–836.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). ARDL bounds testing approach. *Journal of Applied Econometrics*, 16(3), 289–326.

Petrova, S., & Dimitrov, P. (2025). Institutional quality and the effectiveness of green finance in the European Union. *European Journal of Political Economy*, 78, 102345. <https://doi.org/10.1016/j.ejpoleco.2024.102345>

Polzin, F. (2017). Mobilizing private finance for low-carbon innovation: A systematic review. *Research Policy*, 46(2), 287–302. <https://doi.org/10.1016/j.respol.2016.10.003>

Popp, D. (2020). The economic benefits of renewable energy. *Nature Energy*, 5(6), 422–429. <https://doi.org/10.1038/s41560-020-0619-1>

- Porter, M. E., & van der Linde, C. (1995). Toward a new conception of environmental competitiveness. *Journal of Economic Perspectives*, 9(4), 97–118. <https://doi.org/10.1257/jep.9.4.97>
- Qamruzzaman, M., & Karim, S. (2023). Clarifying the relationship between green investment, financial openness, and renewable energy consumption. *Heliyon*, 9(11), e21083. <https://doi.org/10.1016/j.heliyon.2023.e21083>
- Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(S5), S71–S102. <https://doi.org/10.1086/261725>
- Ruiz, J. G., Arboleda, C., & Botero, S. (2016). A proposal for green financing as a mechanism to increase private participation in sustainable water infrastructure systems: The Colombian case. *Procedia Engineering*, 145, 180–187.
- Russo A, Mariani M, Caragnano A (2021) Exploring the determinants of green bond issuance: going beyond the long-lasting debate on performance consequences. *Bus Strateg Environ* 30(1):38–59
- Sadorsky, P. (2009). Renewable energy consumption and economic growth. *Energy Economics*, 31(3), 456–462.
- Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. *Energy Policy*, 37, 4021–4028.
- Sadorsky, P. (2010). Renewable energy consumption, output, and oil prices in OECD countries. *Energy Economics*, 31(3), 456–462. <https://doi.org/10.1016/j.eneco.2009.10.001>

Sari, R., Ewing, B. T., & Soytas, U. (2008). The relationship between disaggregate energy consumption and industrial production in the United States: An ARDL approach. *Energy Economics*, 30, 2302–2313.

Semieniuk, G., Campiglio, E., Mercure, J. F., Volz, U., & Edwards, N. (2021). Low-carbon transition risks for finance. *Nature Climate Change*, 11(2), 109–117.
<https://doi.org/10.1038/s41558-020-00984-7>

Sen, S., & Ganguly, S. (2017). Opportunities, barriers, and policy recommendations for scaling up solar energy in India. *Renewable and Sustainable Energy Reviews*, 78, 409–418.
<https://doi.org/10.1016/j.rser.2017.04.056>

Shahbaz, M., et al. (2015). Energy consumption and growth nexus. *Renewable and Sustainable Energy Reviews*, 44, 79–91.

Shahbaz, M., Loganathan, N., Zeshan, M., & Zaman, K. (2015). Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. *Renewable and Sustainable Energy Reviews*, 44, 576–585.
<https://doi.org/10.1016/j.rser.2015.01.017>

Sun, Y., Guan, W., Cao, Y., & Bao, Q. (2022). Role of green finance policy in renewable energy deployment for carbon neutrality: Evidence from China. *Renewable Energy*, 197, 643–653.

Taghizadeh-Hesary F, Rasoulinezhad E, Yoshino N (2019) Energy and food security: linkages through price volatility. *Energy Policy* 128:796–806

Taghizadeh-Hesary F, Yoshino N (2019) The way to induce private participation in green finance and investment. *Financ Res Lett* 31:98–103

- Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds?. *J Corp Finance*, 61, 101427.
- Tiwari, A. K. (2011). A structural VAR analysis of renewable energy consumption, real GDP and CO₂ emissions: Evidence from India. *Economics Bulletin*, 31, 1793–1806.
- Wang, R., Zhao, X., & Zhang, L. (2022). Research on the impact of green finance and abundance of natural resources on China's regional eco-efficiency. *Resources Policy*, 76, 102579.
- Wang, X., & Wang, Q. (2021). Research on the impact of green finance on the upgrading of China's regional industrial structure from the perspective of sustainable development. *Resources Policy*, 74, 102436.
- Wani, N. A., Ahmad, W., & Akther, S. (2025). Does renewable energy drive economic growth? Analyzing the role of green energy investments in India. *European Economic Letters*, 15(2), 1496–1508.
- Weber, O. (2010). Social banking and sustainability metrics. *Journal of Business Ethics*, 92(1), 307–324. <https://doi.org/10.1007/s10551-009-0154-2>
- Weber, O. (2017). *Sustainable finance and banking: The financial sector and the future of the planet*. Palgrave Macmillan.
- Wiśniewski M, Zieliński J (2019) Green bonds as an innovative sovereign financial instrument. *Ekonomia i Prawo Econ Law* 18(1):83–96
- World Bank. (2022). World development indicators. <https://data.worldbank.org>

- Xiao, C., & Tabish, R. (2025). Green finance dynamics in G7 economies: Investigating the contributions of natural resources, trade, education, and economic growth. *Sustainability*, 17(4), 1757. <https://doi.org/10.3390/su17041757>
- Yoshino N, Taghizadeh-Hesary F, Nakahigashi M (2019) Modelling the social funding and spill-over tax for addressing the green energy financing gap. *Econ Model* 77:34–41
- Yoshino, N., Taghizadeh-Hesary, F., & Otsuka, M. (2021). Covid 19 and optimal portfolio selection for investment in sustainable development goals. *Finance Res Lett*, 38, 101695.
- Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, 98, 39–60. <https://doi.org/10.1016/j.jbankfin.2018.10.012>
- Zhang, D., & Zhou, P. (2016). The impact of green credit policy on economic growth and environmental quality in China. *Journal of Cleaner Production*, 112, 1600–1608. <https://doi.org/10.1016/j.jclepro.2015.10.058>
- Zhang, Y., Sun, L., & Mohanty, S. (2023). Financing gaps in achieving the SDGs: The role of green finance. *World Investment Report*. UNCTAD.
- Zhao, L., Gu, J., Abbas, J., Kirikkaleli, D., & Yue, X.-G. (2023). Does quality management system help organizations in achieving environmental innovation and sustainability goals? A structural analysis. *Economic Research-Ekonomika Istraživanja*, 36(1), 2484–2507.
- Zhou X, Cui Y (2019) Green bonds, corporate performance, and corporate social responsibility. *Sustainability* 11(23):6881

Zhou, H., & Xu, G. (2022). Research on the impact of green finance on China's regional ecological development based on system GMM model. *Resources Policy*, 75, 102454.

Zhou, X., Tang, X., & Zhang, R. (2020). Impact of green finance on economic development and environmental quality: A study based on provincial panel data from China. *Environmental Science and Pollution Research*, 27(16), 19915–19932.

Zhou, Y., & Chen, H. (2024). Green finance and economic growth: Moving beyond environmental outcomes. *Environmental Economics and Policy Studies*, 26(4), 567–584.
<https://doi.org/10.1007/s10018-023-00398-7>