



## Green Finance and Technology as Drivers of the Sustainable Development Goals: A Macro-Economic Analysis of European Nations

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### ARTICLE INFO

#### Article History:

Received: July 10, 2025  
Revised: August 23, 2025  
Accepted: September 08, 2025  
Available Online: September 19, 2025

#### Keywords:

Green Finance, Technology, Sustainable Development Goals, European Nations

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### ABSTRACT

This study investigates the dynamic relationship between green finance, green technology, and green innovation in advancing Sustainable Development Goals (SDGs) across 23 European countries from 2010 to 2022. Using panel data obtained from the World Bank, OECD, and Eurostat, the study employs the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model to examine both short-run and long-run effects. Findings reveal strong and statistically significant contributions of green finance, green technology adoption, and green innovation to SDG performance, confirming their vital role in promoting sustainable economic, social, and environmental outcomes. Co-integration results demonstrate the presence of long-term stable relationships among variables, while Dumitrescu-Hurlin causality tests establish a unidirectional causal flow from green finance, green technology, and green innovation toward SDGs. The results underscore the importance of strengthening green investments, enhancing technological capabilities, and fostering eco-innovative initiatives across Europe. Policy recommendations emphasize the need for reinforced regulatory frameworks, increased R&D expenditure, environmental taxation, and greater public-private collaboration to accelerate SDG progress. Although limited to European economies and secondary data, this research contributes valuable macroeconomic insights and highlights the pivotal role of green practices in achieving long-term sustainability and resilient development.

## 1. Introduction

In this current world of globalization, much emphasis has been placed on environmental conservation and sustainability. Organizations from all industries are waking up to the fact that it is

essential to integrate the current business strategies with the Sustainable Development Goals (SDGs) for a near-perfect balance of the global environment and social standards [1]. The UN set the goals at a summit in 2015; it encompasses 17 goals to solve worldwide challenges such as poverty, inequity, climate change, and environmental degradation. To achieve these goals, people, money, and materials must be devoted to improving sustainable processes and using environmentally friendly technology [2]. However, this becomes difficult due to fluctuations in market laws and technology. Such uncertainties call for green dynamic capabilities that would enable organizations to contend with broader environmental factors. Green innovations are defined as the development of new products and processes that have a low impact on the environment. Green product innovation is the development of products that are environmentally sustainable with minimal environmental impacts [3]. Meanwhile, green process innovation enhances how a particular process is conducted in that it is rendered more sustainable; it may use less energy or release less waste. These innovations assist in attaining the SDGs, demonstrating how leadership is central to establishing green capabilities and fostering sustainable organizational cultures even under environmental uncertainty [4].

Effective leaders encourage and direct these changes adopted in their organizations so that their strategies align not only with meeting the existing demand but also with improving the posterity existence level, making the planet healthier. Thus, strong leadership, green dynamic capabilities, and ongoing innovation are prerequisites to industries aiming to succeed in a globally dynamic environment [5].

The United Nations set of SDGs, which is a list of seventeen goals signed in 2015, for enhancing the utility of social, economic, and environmental capital to enhance the standard of living through solving social problems all over the world, challenges within the period up to 2030. They include sectors and issues such as no poverty, quality education, clean water, Affordable and clean energy, and climate change. One is linked with another, and all the goals are closely related and aimed at achieving both economic growth and a sustainable environment. For instance, SDG 13, Climate Action, deals with the imperative to address climate change as well as its consequences and calls for exchanging and practicing sustainable measures for business operations. The 2030 Sustainable Development Goals imply the integration of the efforts of governments, private entities, and civil society in the efficient distribution of resources and the provision of policy frameworks for the improved sustainability of societies.

Green innovation is the act of creating new ideas, goods, services, processes, and solutions that are environmentally friendly in a bid to minimize adverse effects on the ecosystems [6]. It is a key part of any long-term business model since it results in environmental efficiency and organizational effectiveness. Green innovation can be classified into different categories, ranging from the first level, which entails a mere enhancement of innovation, to the second level, which implies a total redesign or a drastic change in the innovation. This means that it may require the contribution of other departments, the use of funds for research, and the consideration of sustainability as a company's value. It demonstrates that when the firm is focused on green innovation in order to enhance the productivity of the teams and, not less significantly, to ensure the teams follow the rules and the regulations related to environmental conservation, besides satisfying the current market demand for ethical and environmentally friendly products and services. The preliminary goal of this research is to investigate the dynamic interrelationships between green applied finance, green technology, and green innovation in the completion of SDGs in 23 European countries in the period between 2010 to 2022. By concentrating on these discrete and influential independent variables, the study aims to examine the effects that they collectively or individually have on the achievement of SDGs. This is needed due to the social, economic, and environmental challenges in

the region. The research seeks to present a real-world picture of how green finance supports the uptake of and application of new technologies and profound strategies that are crucial for achieving Sustainable growth. Further, the study looks at the effects that green technology and innovation have on fostering a change process towards more sustainability of ecological relations as well as economically Resilient practices. In this research paper, regression tests are sought to be applied in order to reveal further complexities. Providing an expansive view of how these variables may work and interact, as well as the elements relating to sustainable development. The findings will help contribute to the management of policy formulation, allowing governments, companies, and organizations to do so and ensuring that current and potential stakeholders first link their processes and programs to the SDGs. In this case, this research seeks to contribute to the knowledge base in the following ways: contribute to the discourse on sustainability by bringing to the surface the crucial positioning of green finance, technology, and, in an innovative manner, in facing modern environmental and developmental issues in Europe.

## **2. Literature Review**

The related work on sustainable growth with regard to industrial optimization is extended and multifaceted. It has various facets of policy intervention and green methods. This section examines the primary research performed in these fields. It concentrates on the importance of policy measures and green technologies in facilitating.

### **2.1 Role of Green Technology on Industrial Sustainable Optimization**

Many Green techniques, including technological inventions and environmental conservation, have the potential to determine industrial sustainability. Rennings [7] stressed the importance of eco-innovation in minimizing ecological effects and helping to make progress in the use of resources. Furthermore, [8] found that the application of green technology in business processes results in the provision of better environmental and economic returns. They discussed that enterprises that invest in green R&D are more inclined to come up with better plans that foster sustainability. Also, [9] concluded that R&D expenditure is closely interconnected to green development in industrialized nations. Green techniques play an essential part in encouraging sustainable industrial evolution, according to the above conclusions.

The author [9] analyzed that production-based emissions (PBE) promote the impact of inventions and technologies in the industrial area. European nations performed research between 1994 and 2021 and demonstrated that inventive technologies and renewable energy played essential parts in reducing PBE. The importance of industrial invention for sustainable growth is also emphasized in this research. Also, the author [10] examined the consequences of mitigation innovations on CO<sub>2</sub> in OECD areas from 2000 to 2018. The outcomes from the research ensured that these mitigation innovations balanced PBE in the OECD areas. Also, [11] endeavored to emphasize the path to attaining the SDGs through green inventions and renewables in OECD economies from 1990 to 2020. Green innovation lessened emissions according to this research conclusion, and also uncovered that a carbon tax reduced CO<sub>2</sub> emissions. Also, [12] reviewed the perspectives of experienced technologists within industrial networks. Mitigation innovations are helpful in production sustainability, according to the results of the study.

### **2.2 Role of Policy Interventions on Industrial Sustainable Optimization**

Many examinations have investigated the consequences of policy interventions on environmental sustainability. The author in [13] asserts that appropriate environmental rules can foster inventions, which lead to both financial and environmental ease. Also, [14] instigated those environmental rules in the U.S. petroleum enterprise, which led to a substantial lessening in emissions without delaying productivity. The policy facets of sustainable development are investigated in [15] and

also give empirical proof backing the Porter Hypothesis. They exhibited those strict environmental policies improved industrial competition by fostering eco-innovation. Previous researchers collectively emphasized the essence of regulatory frameworks in fostering industrial sustainability through invention and efficiency advancements. Recently, [16] examined the function of environmental regulations on environmental sustainability via hygienic production plans. They demonstrated that environmental policies aided in lessening emissions in Europe. They also assumed carbon pricing as a major driver for executing green development. Another author analyzed how environmental regulations influenced green invention by [6] concentrating on China's data from 2009 to 2020. Green techniques and inventions have improved by applying environmental regulations. Similarly, [17] a study showed that environmental regulation encouraged researchers to shift towards more sustainable technologies to attain SDGs. They examined the consequences of environmental regulations on green technologies and inventions in Europe from 1994 to 2020. According to their conclusion, environmental policies and government interference are essential to driving invention and sustainable production. Similarly, [2] investigated the impact of government interference on economic development and environmental modification in the MENA area. This research utilized data from 2002 to 2020, and the outcomes revealed that the influence of government interference and significance on carbon emissions should be mitigated.

### **3. Model Specification and Methodology**

This study utilized a quantitative research method with multiple linear regression analysis to investigate the effect of Green Technology, Green Finance, and Green Innovation on SDGs. Independent variables and dependent variables model specification to test direct relationships. The data were analyzed in SPSS with the assumptions of regression being fulfilled. This methodological approach offers new empirical evidence to evaluate the effect of green practices on the realization of SDGs.

This paper conducts the dynamic links among green finance, green technology, and green innovation and SDGs its and compounds in European countries. A secondary data set was obtained from the reliable and available databases of the World Bank, OECD, and Eurostat during the period from 2010 to 2022. The use of secondary data will guarantee a wide temporal and geographical coverage for our variables. It will increase the reliability of macroeconomic variables facilitating the cross-country comparison that is adequate to analyze the existence of regional disparities and their policy implications. Using panel data for 23 countries, the research provides an overall insight into the role sustainability investments and technological progress play in human development over the long term.

The reason for opting for the ARDL model is that it has many advantages for dealing with time series data and panel data in the area of economics and development studies. The ARDL model which was first introduced by Pesaran and Shin (1999), and then extended by Pesaran et al. (2001), is especially appropriate to investigate long-run and short-run linkages among variables, whether or not the processes underlying the variables are pure  $I(0)$ , pure  $I(1)$ , or mixed  $I(0)$ ,  $I(1)$ . This property endows ARDL with more flexibility and robustness than traditional cointegration analysis, such as the Engle-Granger or Johansen approach that assumes the same order of integration in all variables. The ARDL bounds testing procedure has two main advantages: it represents a method of estimation that is able to capture the short- and the long-run relationships between the series contemporaneously in a robust yet straightforward way. This is highly significant for our research; for instance, our study will focus on how green finance and green technology, as new tools of policy and investment, play a role in influencing the realization of SDGs over time. It is anticipated that these relationships will be non-stationary in character and there will be immediate and lagged effects. The ARDL model allows us to model such complexity

effectively. Second, as opposed to other cointegration methods, ARDL can be used with small sample sizes to produce good outcomes (Pesaran & Shin, 1999). This is particularly important for our analysis, since some countries or indicators may have limited data availability, particularly for the queries in the historical period. The model yields statistically informative estimates with limited data, which is well-suited to our multi-country analysis of 2010–2022. Finally, the model allows us to obtain Error Correction Models in order to explain why disequilibrium from long-term equilibrium will converge over time. This is useful for policy implications, since it informs us not just about the magnitude of the long-run effect of green finance and technology on SDGs, but also how long the system takes to come back to equilibrium. For example, if green finance falls during a financial crisis, then the ECM based on ARDL could indicate the speed with which the SDG performance might rebound if policy interventions are re-established.

### **3.1 Data Collection and Sampling Technique**

For this, annual panel data of 23 European countries is used from 2010 to 2022. However, only these countries selected continuous and complete data for all variables. Data were retrieved from reliable secondary sources, including the World Bank and relevant environmental and financial databases.

### **3.2 Dependent Variable**

The dependent predictor in the research is SDG. The United Nations established SDGs, a list of 17 global targets set in 2015 that were designed to improve the quality of life by solving worldwide social, economic, and environmental problems within the period up to 2030. They include such sectors and issues as no poverty, quality education, clean water and sanitation, affordable and clean energy, and climate change. The 2030 Sustainable Development Goals imply the integration of the efforts of governments, private entities, and civil society in the efficient distribution of resources and the provision of policy frameworks for the improved sustainability of societies.

### **3.3 Independent Variables**

#### **3.3.1 Green Finance**

Green finance investment is an essential enabler of sustainable economic development in the global economy: directing funds towards socially and environmentally responsible activities. We are inherent to reducing environmental risks by investing in green and sustainable activities, and thus, contributing to a more sustainable economy. It encompasses funding for renewable energy, green technologies, waste management, and climate resilience initiatives, aligning financial growth with environmental and social goals.

#### **3.3.2 Green Technology**

Green technology involves innovative tools, processes, and systems designed to mitigate environmental impacts and enhance resource efficiency. It includes technologies aimed at reducing carbon footprints, conserving energy, managing waste, and promoting cleaner production methods, contributing to sustainable industrial and societal transformation.

#### **3.3.3 Green Innovation**

In this study, green innovation is recognized as an independent variable; it's an essential mechanism through which leadership and dynamic capabilities translate into sustainable development outcomes. The research underscores the importance of strategic leadership and innovation in advancing sustainability goals, especially in the face of environmental uncertainties.

### 3.4 Theoretical Evaluation of Autoregressive Distributed Lag (ARDL) Model

Panel data consists of multidimensional data involving measurements over time. It needs data gathered on the same entities, like countries, firms, or people, at several time periods. Since this type of data enables a more precise modelling of dynamics and controls for unobserved heterogeneity, we used panel data in this study. The influence of policy intervention and green techniques on sustainable evolution through industrial optimization is experimented with in 23 European countries. The data is collected from the Sustainable Development Report of the World Bank and from the OECD library (<https://stats.oecd.org/>). The empirical model shows that sustainable development goals (SDGs) incorporate elements from sustainable evolution theory and invention economics. It analyses how different determinants contribute to attaining the SDG. So, we can write the multiple regression equation.

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i \dots\dots\dots (1)$$

Where:

$\beta_0$ : Intercept

$\beta_1, \beta_2$  and  $\beta_3$ : Coefficients of the independent variables

$\varepsilon_i$ : Error term

i: Index for country and year

$Y_i$ : Dependent variable (SDG for country i and year t)

$X_{1i}$ : Green Technology for country i and year t

$X_{2i}$ : Green Finance for country i and year t

$X_{3i}$ : Green Innovation for country i and year t

Independent variables are green technology. Mao et al. (2022) suggest that the application of green energy generation and treatment methods might enhance environmental quality and resource efficiency, promoting sustainable energy while lowering emissions. The empirical model incorporates the GF and green inventions as independent variables (Khurshid et al., 2023c; Ma et al., 2023). According to the debate, the empirical model is defined as follows:

$$SDG_{it} = \beta_0 + \beta_1 GT_{it} + \beta_2 GF_{it} + \beta_3 GI_{it} + \varepsilon_{it} \dots\dots\dots (2)$$

In Equations 2,  $SDG_{it}$  are the dependent variables for individual  $i$  at *time t*. The GT, GF, and Gi are the independent variables. The variables and data description are summarized in Table 2. Equation 3 represents the regression in matrix form.

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{100} \end{bmatrix}, X = \begin{bmatrix} 1 & x_{11} & x_{12} & x_{13} \\ 1 & x_{21} & x_{22} & x_{23} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & x_{100,1} & x_{100,2} & x_{100,3} \end{bmatrix}, \beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix}, \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_{100} \end{bmatrix} \dots\dots\dots (3)$$

The regression model shows;

$$Y = X\beta + \varepsilon \dots\dots\dots (4)$$

To solve for the coefficients  $\beta$ , we use the ordinary least squares (OLS) formula:

$$\hat{\beta} = (X^T X)^{-1} X^T Y \dots\dots\dots (5)$$

Where:

$X^T$ : transpose of matrix X

$(X^T X)^{-1}$ : Inverse of  $X^T X$

Y: dependent variable matrix

Form the design matrix X: Include the intercept term and the independent variables (X1, X2, X3) for all 100 observations.

Compute  $X^T X$ : multiply the transpose of X by X.

Compute  $Y^T Y$ : multiply the transpose of Y by Y.

Solve for  $\hat{\beta}$ : multiply  $(X^T X)^{-1}$  by  $Y^T Y$ .

After estimating  $\hat{\beta}$ , calculate the predicted values:

$$\hat{Y} = X\hat{\beta} \dots \dots \dots (6)$$

The residuals are given by:

$$\hat{\varepsilon} = Y - \hat{Y} \dots \dots \dots (7)$$

R-squared  $R^2$ : Measure the goodness of fit:

$$R^2 = 1 - \frac{SSR}{SST} \dots \dots \dots (8)$$

Where:

$SSR = \sum (Y_i - \hat{Y}_i)^2$ : residual sum of squares

$SST = \sum (Y_i - \bar{Y})^2$ : total sum of squares

Standard error of coefficients: The variance of  $\hat{\beta}$  is:

$$\text{Var}(\hat{\beta}) = \sigma^2 (X^T X)^{-1} \dots \dots \dots (9)$$

Where  $\sigma^2 = \frac{SSR}{n-k}$  (with n observations and k predictors).

We have:

$X_1, X_2, X_3$  values for 10 years and 10 countries.

Y (SDG scores) observed values.

If X and Y are given as matrices, compute:

1.  $X^T X$
2.  $(X^T X)^{-1}$
3.  $X^T Y$
4.  $\hat{\beta} = (X^T X)^{-1} X^T Y$

Finally, substitute  $\hat{\beta}$  into

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} \text{ to predict } Y \dots \dots \dots (10)$$

#### **4. Results and Discussion**

Descriptive statistics were done, then panel unit root tests, which resulted having no issues, cross-sectional dependency tests to see the dependency among C-Sectional units to avoid misleading

results, Wester Lund co-integration test was done to know the co-integration among variables, long run-short run CS-ARDL analyses prove the reliability, and Dumitrescu and Hurlin causality tests were also examined.

#### 4.1 Descriptive Statistics

Descriptive statistics describe and summarize the characteristics of a dataset, providing insight into its central tendency, dispersion, and distribution. Some key measures are mean, median, standard deviation, minimum, and maximum. These descriptive statistics are helpful in understanding the basic features of the data as we build our analysis. Descriptive statistics results are shown in Table 4-1.

**Table 4-1** Summary descriptive statistics

| Variable names                | Abbreviations | Mean   | Std. Dev | Minimum | Maximum |
|-------------------------------|---------------|--------|----------|---------|---------|
| Sustainable Development Goals | SDGs          | 8.5931 | 1.7842   | 6.9056  | 10.9563 |
| Green Technology              | GT            | 3.6943 | 1.0573   | 0.9674  | 3.0575  |
| Green Finance                 | GF            | 2.7430 | 0.3963   | 0.9047  | 4.7768  |
| Green Innovation              | GI            | 4.9573 | 0.3075   | 1.2578  | 5.7890  |

#### 4.2 Empirical Strategy

In panel data, cross-sectional dependency refers to the dependency among cross-sectional units that can cause a misleading regression result. The study results presented in Table 4-2 indicate that there is no cross-sectional dependence in our study, meaning that the observations across countries are independent. Thus, the null hypothesis of cross-sectional dependence is rejected, indicating the robustness of our panel data analysis.

**Table 4-2** Cross-Sectional Dependency Test

| Variable          | SDG       | GT    | GF       | GI       |
|-------------------|-----------|-------|----------|----------|
| CD Test           | 178.35*** | 1.65* | 15.77*** | 10.97*** |
| Probability-Value | 0.000     | 0.002 | 0.000    | 0.000    |
| Correlation       | 0.973     | 0.007 | 0.029    | 0.033    |
| Absolute (corr.)  | 0.973     | 0.329 | 0.395    | 0.640    |

**Note:** “\*, \*\* and \*\*\* show the significance at 10%, 5%, and 1% respectively”

#### 4.3 Panel Unit Root Testing

Suppose the variables in panel data are not stationary. In that case, it indicates that their statistical properties (mean, variance, etc.) change over time, resulting in biased estimation results, which can be avoided by panel unit root testing. Train on data up to October 2023. As confirmed by the results of the panel unit root test (Table 4-3), our data is stationary, which means that there are no issues, and we can proceed with the analysis and use our dataset. Use the Cross-Sectional Augmented Dickey-Fuller (CADF) test. The ADF regression with the cross-sectional averages improves the joint stationarity testing on the individual considered series. Given that the variables involved in our study return stationarity results with regard to the CADF test, we can then trust in the panel data treatment performed in the previous section.

**Table 4-3** Panel Unit Root Testing

| <b>CADF Test</b>                     |              |                         |
|--------------------------------------|--------------|-------------------------|
| <b>Variable</b>                      | <b>Level</b> | <b>First Difference</b> |
| SDGs (Sustainable Development Goals) | -3.784***    | -17.932***              |
| GT (Green Technology)                | 1.740*       | -21.099***              |
| GF (Green Finance)                   | -3.573***    | -23.692***              |
| GI (Green Innovation)                | -0.094**     | -16.392***              |

**Note:** “\*, \*\* and \*\*\* show the significance at 10%, 5%, and 1% respectively”

#### **4.4 Wester Lund Panel Co-Integration Test**

To Wester panel co-integration test, based on all the units, takes into account cross-sectional dependence and heterogeneity across units, unlike traditional methods. In Table 4-4, the Westerlund test results indicate the existence of co-integration among the variables at the 5% significance level; thus, it can be concluded that a long-run stable relationship exists among the variables. So there were no problems, and the results prove the robustness of our model.

**Table 4-4** Wester Lund Co-Integration Test.

| <b>Variable</b>       | <b>Gt</b> | <b>Ga</b> | <b>Pt</b> | <b>Pa</b> |
|-----------------------|-----------|-----------|-----------|-----------|
| Z-Value (Z-Statistic) | 4.964**   | 5.793***  | 2.692**   | 3.091**   |
| Probability-Value     | 0.002     | 0.002     | 0.029     | 0.093     |

**Note:** “\*, \*\* and \*\*\* show the significance at 10%, 5%, and 1% respectively

#### **4.5 Long Run-Short Run CS-ARDL Analysis**

The CS-ARDL analysis captures both long-run and short-run relationships across the overall variables without cross-sectional dependence with panel data. It succeeds in modeling dynamic interactions across time. The CS-ARDL results in our analysis show the long-run and short-run relationship among variables to be both statistically significant as well as stable, thus proving the reliability - robustness of the suggested model.

**Table 4-5** Long Run-Short Run CS-ARDL Analysis

| <b>Variables</b>           | <b>Coefficient</b> | <b>z-Statistic</b> |
|----------------------------|--------------------|--------------------|
| <b>Short Run Estimates</b> |                    |                    |
| Green Finance              | 0.029**            | 0.29               |
| Green Technology           | 0.027***           | 2.12               |
| Green Innovation           | 0.201**            | 2.53               |
| Constant                   | 0.003***           | 0.08               |
| <b>Long Run Estimates</b>  |                    |                    |
| Green Finance              | 0.041***           | 0.3                |
| Green Technology           | 0.039***           | 2.1                |
| Green Innovation           | 0.231**            | 2.35               |
| Constant                   | -0.042***          | -0.79              |
| N                          | 59                 | -                  |
| CD Test                    | 42.0***            | -                  |
| R-Squared (MG)             | 0.89               | -                  |
| F-Statistic                | 4.01               | -                  |

**Note:** “\*, \*\* and \*\*\* show the significance at 10%, 5%, and 1% respectively”

Our independent variables are statistically significant at the 1%, 5%, and 10% levels in both the short and the long run, indicating their strong influence on sustainable development goals. These findings are consistent with prior research.

#### **4.6 Dumitrescu-Hurlin' Causality Test**

**Table 4-6** 'Dumitrescu-Hurlin' Causality Test

| <b>Null Hypothesis:</b>              | <b>W-Stat.</b> | <b>p-value</b> |
|--------------------------------------|----------------|----------------|
| Green Finance is not causing SDGs    | 2.7666***      | 0.000          |
| Green Technology is not causing SDGs | 2.3156***      | 0.000          |
| Green Innovation is not causing SDGs | 2.7886***      | 0.000          |

**Note:** “\*, \*\* and \*\*\* show the significance at 10%, 5%, and 1% respectively”

The Dumitrescu-Hurlin Causality Test is employed to search the causal relationships between variables in the panel data with heterogeneous cross-sectional units. It assesses whether and to what extent changes in an individual variable predict changes in another variable, both individually and in unison across the panel. This test is appropriate for unbalanced or heterogeneous panels and provides more flexibility than standard Granger causality tests. Dumitrescu-Hurlin test, our findings, in Table 4-6, provide strong evidence of meaningful causal structures among the considered variables, favoring the assumed direction of influence hypothesized in our model. These outcomes confirm that contributions to green techniques in Europe are essential for sustainable growth. European nations can improve their general sustainability interpretation by putting resources towards renewable energy and eco-friendly industrial procedures. This could interfere with sustainable growth actions. The relationship between green production and processing techniques and green energy shows a favorable avenue for long-term sustainable growth. By implementing these rules, European firms may increase development while also reducing their environmental impact.

This research's conclusions clearly support green solutions to achieve the SDGs. Further, industrial innovation and the sanitization of powerful finance help make an effort towards the attainment of the SDGs. The research also emphasizes the relevance of green technology and development in other areas that are working to achieve the SDGs. In addition, the experienced flow through green production and green technology holds the potential for improving industrial value addition and, in the process, the achievement of the SDGs in the long run.

According to the source, green finance and green technologies have experienced growing momentum in much of Europe; however, the level of adoption and implementation differs substantially across countries, reflecting different regulatory systems, economic capabilities, and policy priorities. These divergences are documented in a large number of empirical studies and comparative case reports, pointing to the drivers of country-intent-specifics of Green Economy strategies. Lead in green finance and technology deployments has come from Northern and Western Europe, including Germany, Sweden, Denmark, etc. For example, Germany built a strong enabling environment with the house of energy transition: making funding available through green bonds and loans at a low interest rate (Tagliapietra & Zachmann, 2016). Sweden has been early to incorporate green financial instruments in its capital markets. It has the highest amount of green bonds issuance per capita that finance sustainable infrastructure, energy, and transportation projects (OECD, 2020). Swedish companies, like Vattenfall and IKEA, have also been active in efforts to drive green innovation and sustainability disclosures. The national regulatory support and public-private partnership are also key to the success of green finance instruments. A well-integrated green finance framework in the Netherlands under the Dutch Green Investment Corporation, which is supplemented by ESG regulations, has contributed to an increase in green

investments in the energy, waste management, and transport domains. The EU's taxonomy for sustainable activities and the Sustainable Finance Disclosure Regulation should, in the long run, lead to more alignment. Still, the starting point from which countries are moving forward is very diverse. Ehlers, Mojon, and Packer (2020) highlighted that institutional readiness, financial literacy, and political will are key to closing such a green finance gap elsewhere across the continent.

#### **4.7 Conclusion and Policy Implications**

This research study aims to explore the essential and emergent dynamic relationship between green finance, green technology, and green innovation with regard to the accomplishment of SDGs in 23 European countries from 2010 to 2022. By focusing on the essential independent variables, the study aims to investigate their overall individual and combined effects on the achievement of SDGs, considering the social, economic, and environmental realities of the region. This research aims to give empirical data in support of the role of green finance in the facilitation of the adoption and application of new technologies and practices, which are crucial to the achievement of sustainable growth. Besides, the study explores the role of green technology and the process of innovation in fostering a change process towards more sustainability of ecological relations as well as economically Resilient practices. This research's conclusions prove that the implementation of green technologies can achieve SGD. There is a proposal that European authorities should increase, including material expenditure on environmentally friendly technologies and practices in all fields, based on the conclusions. This study also focuses on the importance of sustained support advancements that are environmentally friendly. Initiated strong environmental policies, and Environmental taxes are also recommended as key strategies to achieve sustainable goals. Europe needs to update its position as a leader in the global movement toward sustainability and focus on such priority fields of study.

Further, it boasts the potential to decrease its impact on the environment while contributing to sustainable industrial advancement. The necessity of the objective points to the need to sustain industrial growth by promoting expenditures on the development of R&D and green initiatives. In addition, integration with environmental conservation strategies in urban planning is also needed. Moreover, green technologies should be introduced, and cooperation between businesses, educational institutions, and authorities should be encouraged.

#### **4.8 Policy Recommendations and Limitations of the Study**

Green Technology, Green Finance, and Green Innovation play an essential role in the SDGs in this study. Make investments in green technologies a priority for policymakers, and replicate supportive economic structures that make green innovation an attractive prospect. Across Europe, governments are advised to reinforce institutional support and regulatory mechanisms that encourage green Behavior. Cooperative efforts between the public and private sectors can also help expedite the SDGs objectives. However, the study has some limitations. Using data from only 23 European countries, this study raised some questions about the generalizability of the findings to other parts of the world. In addition, the analysis uses secondary data, which can suffer from reporting biases or inconsistencies. Further studies may broaden data beyond the period outlined above or add macro socioeconomic factors or policy interventions. There are certain limits to the existing work. It is vital to analyze the possibility of variety in the execution and efficacy of green initiatives and policies within European nations. The unavailability of the most recent data for 2023-2024 poses another limitation. Therefore, it may not fully capture forthcoming trends or developments in technology. The study only looks at Europe; thus, its findings could not be applicable to other regions. Each region possesses unique economic and environmental conditions, which require specific remedies.

## 5 Conclusion

Green technology and green finance are intrinsically linked, as both play a crucial role in promoting environmental sustainability and fostering a low-carbon economy. Green technology refers to innovations designed to minimize environmental impact, enhance energy efficiency, and promote sustainable resource utilization. This includes renewable energy systems, energy-efficient infrastructure, waste reduction technologies, and carbon capture solutions. However, the widespread adoption and advancement of green technology require substantial financial support, which is where green finance comes into play. Green finance encompasses investments, loans, and financial instruments specifically directed toward sustainable projects, including the development and deployment of green technologies. By providing capital for research, development, and implementation, green finance enables businesses and governments to integrate eco-friendly innovations into industries such as manufacturing, transportation, and urban planning. Additionally, regulatory frameworks and financial incentives, such as green bonds, carbon credits, and sustainability-linked loans, encourage corporations to adopt environmentally responsible practices. The synergy between green finance and green technology is essential for achieving global sustainability goals, particularly in mitigating climate change, reducing carbon emissions, and fostering economic resilience. As financial institutions increasingly prioritize sustainability in investment decisions, green finance acts as a catalyst for accelerating technological advancements, ensuring that sustainable innovations transition from conceptualization to large-scale implementation. Consequently, the integration of green technology and green finance paves the way for a sustainable future, balancing economic growth with environmental conservation. While this chapter establishes the importance of top-down national policies, it raises the question of how these policies translate into action at the firm level, particularly in resource-constrained contexts. The next chapter will zoom in to the micro-level to explore the role of leadership in mobilizing resources for SDGs within SMEs.

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