Does Green Transition Harm EU Public Debt?

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Abstract*:* This study examines the impact of green transitions on public debt in 27 European Union (EU) countries, employing the dynamic Generalized Method of Moments (GMM) estimation technique. Covering the period from 2019 to 2024, the empirical results confirm that the green transition increases EU public debt levels. In addition, this study analyzes the threshold level of green transition that does not harm public debt using dynamic panel threshold estimation. The panel threshold findings reveal that the green transition has a significantly negative impact on public debt below the threshold and a significantly positive impact above the threshold. This implies that the green transition increases debt after a certain threshold level. Therefore, the results indicate that while a green transition is necessary to meet climate goals, fiscal prudence and private sector participation are needed for sustainable transitions.

Keywords: green transitions; public debt; european countries; threshold level.

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1. INTRODUCTION

The World Economic Forum's (2024) New Nature Economy report highlighted the urgency of accelerating the green transition as a pathway toward a sustainable economy. This transition primarily focuses on reducing greenhouse gas emissions by adopting environmentally sustainable and low-carbon approaches, such as enhancing the adoption of renewable energy, clean technologies, and energy efficiency. The report emphasizes that approximately $44 trillion over half of the global Gross Domestic Product (GDP)significantly relies on natural resources (World Economic Forum, 2024). The depletion and degradation of these resources, driven by climate change, threaten global supply chains, food security, and financial stability, resulting in substantial economic losses (World Economic Forum, 2024). Thus, global leaders are urged to advance the green transition to ensure long-term environmental sustainability and enhance future well-being.

On the effort to accelerate the green transition, European Union (EU) countries are fully committed to being frontrunners in cutting greenhouse gas emissions. The EU aims to achieve carbon neutrality by 2050, along with an interim goal of reducing carbon emissions by 55% by 2030 (Duwe et al., 2023; Meyer-Ohlendorf et al., 2023). To meet this target, the European Green Deal (EGD) has implemented a wide range of initiatives and projects focused on transitioning to a circular economy to minimize waste and maximize resource efficiency, as well as promoting renewable energy and green technologies to restore biodiversity and reduce emissions. For example, as part of its commitment to decarbonizing the transportation sector and improving sustainable mobility, the EU is investing €422 million in 39 projects to expand alternative fuel infrastructure, including 2,500 electric charging stations, nine green port initiatives, and 35 hydrogen refueling stations throughout Europe's transportation hubs and corridors (European Alternative Fuels Observatory, 2025). Additionally, an energy island in the North Sea is being built to provide Denmark and the Netherlands with a minimum of 3GW of power by 2030, contributing to the goal of reducing greenhouse gas emissions by 70% (European Alternative Fuels Observatory, 2025). About $34 billion will be invested in this energy project, making it the largest infrastructure project capable of providing energy to 3 million households in the EU.
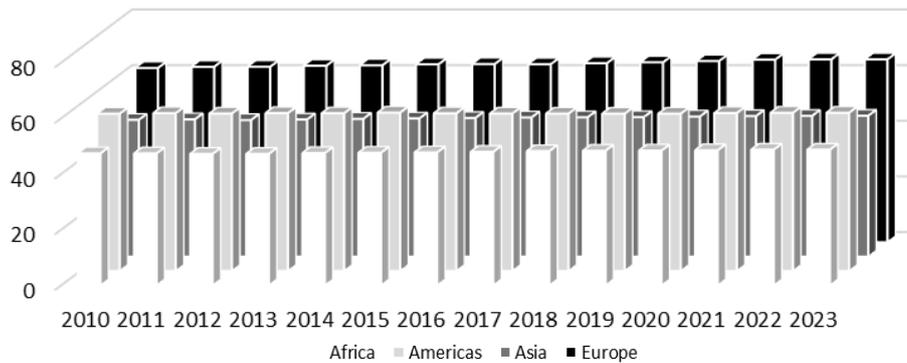
Source: Global Green Growth Institute (2025)

Figure no. 1 – The Green Growth Index

These trends have been highlighted in the analysis of the Green Growth Index, which measures a country's progress in achieving sustainability targets by integrating four key dimensions of efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion. Compared to other regions, EU countries have taken the leading position from 2010 to 2023, with the Green Growth Index rising from 62.59 in 2010 to 65.67 in 2023, showing steady progress (see Figure no. 1). Green growth has been actively promoted by the EU, and Europe's 3% increase in Green Growth Index scores from 2010 to 2023 was slightly higher than that of the Americas, whose index ranged from 56.43 to 57.27, indicating moderate success driven by social equity and environmental quality initiatives. Asia and Africa consistently had the lowest scores, with Asia increasing from 48.99 to 50.51 and Africa slightly rising from 47.96 to 49.56, both remaining in the lower-moderate range. With sustained investment and policy refinements in climate, energy, and environmental strategies, the EU is steadily advancing its green transition toward carbon neutrality while setting a benchmark for other regions to follow.
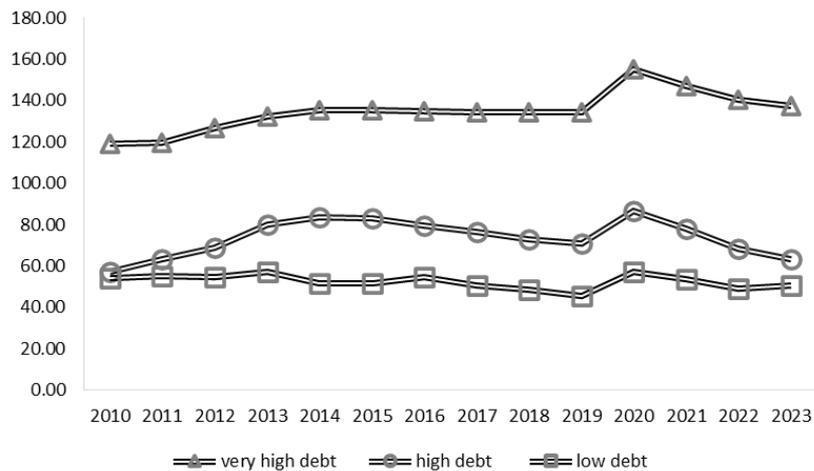

Source: Eurostat (2024)
Figure no. 2 – Public debt across EU

However, concerns over government debt have been rising due to the unprecedented debt levels reached in many EU countries. Figure no. 2 displays public debt across EU countries from 2010 to 2023, specifying that (i) very high debt countries exceed 90% of GDP (Belgium, Greece, Spain, France, Italy, Cyprus, Portugal); (ii) high debt countries range between 60% and 90% of GDP (Germany, Ireland, Croatia, Hungary, Netherlands, Austria, Slovenia, Finland); and (iii) low debt countries have debt below 60% of GDP (Bulgaria, Czech Republic, Denmark, Estonia, Latvia, Lithuania, Luxembourg, Malta, Poland, Romania, Slovakia, Sweden). In parallel, EU countries have committed to green transitions under the EGD through massive investments in renewable energy, infrastructure upgrades, and decarbonization projects. Between 2021 and 2030, the EGD demands a substantial investment of approximately EUR 600 billion per year (see Figure no. 3). Additionally, the EU requires an extra EUR 92 billion to strengthen its capacity to produce net-zero

technologies. These additional investments cannot be covered by the public sector alone, underscoring the fact that the fiscal sustainability of such an aggressive green transition remains a critical concern. While the progress toward transforming the green transition is accelerating sharply, the exhaustion of public debt raises the question of whether green transition efforts are leading to a "debt trap" for EU countries. Therefore, this paper aims to shed light on the impact of the green transition on public debt in EU countries[1]. Moreover, this study explores the threshold levels in the green transition–debt relationship to determine the point at which green transition efforts may hamper or harm public debt in EU countries. The results of this study have significant policy implications, especially when it involves maintaining a balance between goals of sustainability and debt management. Policymakers can develop strategies that optimize the returns on green investments while reducing the financial risks associated with growing public debt by knowing the turning point of the relationship between green transition and debt.
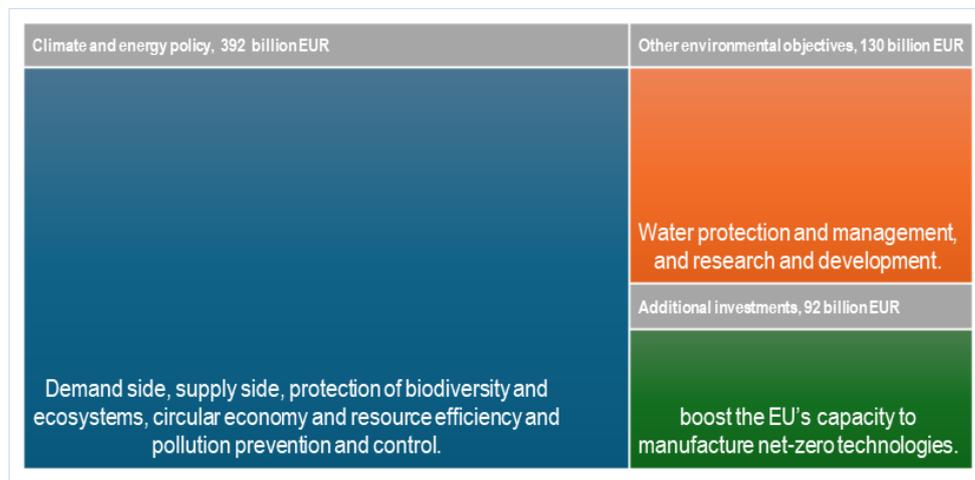
Source: Claeys *et al.* (2023) and Speck *et al.* (2023)

Figure no. 3 – Annual Investment Needs for the EGD (2021–2030)

The remainder of this study is organized as follows. Section 2 presents the literature review. Section 3 describes the data and methodology employed in this study. Section 4 reviews the study's findings, and Section 5 offers conclusions and policy implications.

2. LITERATURE REVIEW

Theoretically, the discussion on existing past studies on the determinants of public debt is presented based on three theories: The Two-Gap Model, Keynesian Economics Theory, and Classical Economic Theory. Chenery and Strout (1966) developed the Two-Gap Model, which highlights the role of the savings gap and trade gap in economic growth. The savings gap indicates the insufficiency of savings in financing investment, while the trade gap reflects low earnings from exports to finance import expenditures. Second, the Keynesian economic theory, as suggested by John Maynard Keynes, supports the fact that deficit expenditure increases public

debt (Elmendorf and Mankiw, 1999). Higher government expenditure and investment not only stimulate economic activity and aggregate output, but they also lead to an increase in public debt. In addition, governmental debt is detrimental, according to classical economic theory, because it raises the burden of interest payments, hinders long-term economic growth, and discourages private investment through excessive borrowing (Salsman, 2017). It relies on the assumption that the economy has self-regulating mechanisms that restore it to its actual output level (Witt, 1997). Thus, the following review of past studies will be presented in three stances, along with the research gap, to highlight the contribution of the study.

According to the Two-Gap theory, inadequate savings and export revenues to cover import expenditures lead to the accumulation of debt to achieve long-term economic growth. This suggests that the trade, and savings are connected to public debt. Drazen (2000), Imbeau (2004), Swaray (2005), Ouhibi et al. (2017), Kirui (2017), and Musah (2023) reported that savings, trade and budget deficit influence public debt. The savings gap emphasizes how savings impact the extent of government reliance on debt. The government often borrows funds to close the financing gap since the national savings (internal resources) are insufficient to fund investments in infrastructure, health care, and education for sustained economic growth. This tends to increase the amount of debt, indicating that savings have a negative impact on the public debt (Swamy, 2015; Kirui, 2017; Musah, 2023). For instance, a study by Musah (2023) on public debt in Ghana points out that savings have a significant negative impact on Ghana's public debt in the long run only, and not in the short run. This implies that a higher savings level does not affect public debt immediately, but it eases external debt over time. Similarly, a higher level of savings increases the supply of loanable funds, which becomes available for investment without the need for borrowing (Swaray, 2005). Additionally, Imbeau (2004) for federated states, Swaray (2005) for less developed countries, Kirui (2017) for Kenya, Omrane Belguith and Omrane (2017) for Tunisia, and Musah (2023) for Ghana revealed that trade has a significant impact on public debt. An expansion in trade raises the country's public debt as the growth of imports exceeds exports. This contributes to a trade deficit, and the government resorts to external borrowing, accumulating the debt level for financing. In Kenya, for instance, Kirui's (2017) findings indicate that a rise in trade, alongside slow economic growth, led to public debt accumulation due to overreliance on imports compared to exports. Therefore, this study hypothesizes that savings and trade have a significant negative and positive influence on public debt, respectively.

Moreover, the Keynesian theory elucidates that higher government expenditure is used to boost aggregate demand, but it tends to result in higher debt due to deficit-financed fiscal policy (Brown-Collier and Collier, 1995; Aspromourgos, 2018; Ncanywa et al., 2018). This has been proven by Asiama et al. (2014), Frimpong and Oteng-Abayie (2006), Asiama et al. (2014), Obeng and Sakyi (2017), and Swamy (2015), who found that government expenditure influences a country's public debt. These studies show that government expenditure raises public debt due to fiscal deficits that cause sustained external and domestic borrowing, thereby leading to debt accumulation. The positive impact of government expenditure on public debt aligns with the Keynesian theory, indicating that excessive government expenditure, particularly in developing countries, often relies on borrowing, raising concerns about debt sustainability (Swamy, 2015; Owusu-Nantwi and Erickson, 2016; Obeng and Sakyi, 2017). Thus, this study hypothesizes that government expenditure has a significant positive impact on public debt.

Classical Economic Theory sees public debt as harmful to economic growth because it discourages foreign investors and private investment (Witt, 1997; Broner *et al.*, 2014) (Saugweme *et al.*, 2019). This occurs through the interest rate channel, where governments require additional funds to meet their obligations as public debt rises, leading to higher interest rates. High rates make it more expensive for the government to borrow funds and deter private sector investment. Besides that, a rise in interest rates further accelerates the level of debt by increasing borrowing costs (Drazen, 2000; Imbeau, 2004; Swaray, 2005; Mupunga and Roux, 2015; Kirui, 2017; Omrane Belguith and Omrane, 2017). Employing the Vector Error Correction Model (VECM), Omrane Belguith and Omrane (2017) examined the impact of the macroeconomic variable of interest rate on Tunisia's public debt. Omrane Belguith and Omrane's (2017) results indicate that interest rates increase Tunisia's public debt, as higher interest payment costs lead to the growth of public debt. On the other hand, Musah's (2023) findings provide a contractionary view of the impact of interest rates on public debt in Ghana. In the short run, higher interest rates lessen the extent of public debt, while in the long run, they accumulate additional debt. Higher interest rates have the short-term effect of discouraging further borrowing and establishing the opposite relationship between interest rates and debt accumulation. Therefore, this study hypothesizes that interest rates have a significant impact on public debt.

Novelty of the study

An extensive number of studies have been conducted on examining the economic and environmental benefits of the green transition, such as Shah *et al.* (2023), Barua (2022), Adebayo *et al.* (2024), Wei *et al.* (2025), and others. As this study aims to examine the impact of the green transition on debt levels, so far only Mammetti *et al.* (2024) and Taghizadeh-Hesary and Rasoulinezhad (2025) have explored the impact of renewable energy transition on developing countries' and mixed advanced and emerging economies' debt. Taghizadeh-Hesary and Rasoulinezhad (2025) interestingly finds that the energy transition lowers developing countries' debt levels, as it lessens the fiscal burden by reducing energy subsidies and the import costs of fossil fuels. This suggests that governments can more effectively spend resources while promoting sustainable energy transitions through renewable energy. Meanwhile, Mammetti *et al.* (2024) demonstrates that the low-carbon transition can increase sovereign debt due to negative growth consequences using stochastic debt sustainability analysis and climate-transition scenarios. However, fiscal adjustments, green growth, and carbon-tax revenue recycling can lessen these debt pressures. By exploring the existing studies on the green transition and debt, we find that this topic is underexplored among scholars, particularly in the context of EU countries.

Table no. 1 – Studies on green transition on debt

Author's	Country	Results	Research hole
Mammetti *et al.* (2024)	15 countries (mixed advanced and emerging economies)	↑Low carbon transition Sovereign debt ↑	Uses scenario-based projections rather than empirical evidence and does not identify threshold effects in the green transition–debt relationship. The findings are not specific to the EU, as the sample includes a mix of advanced and emerging countries.

Author's	Country	Results	Research hole
Taghizadeh-Hesary and Rasoulinezhad (2025)	Developing countries	↑ Energy transition ↓debt	limited to developing countries and assume a linear debt-reducing effect of energy transition, leaving uncertainty about whether similar effects hold in advanced economies such as the EU.

Source: author's own illustration

Table no. 1 displays existing studies examining the impact of the green transition on debt, with a particular focus on developing countries and mixed samples of advanced and emerging economies. This highlights a gap in the literature, as the findings are largely limited to non-EU countries, creating uncertainty as to whether the results are applicable to EU countries. Moreover, Taghizadeh-Hesary and Rasoulinezhad (2025) and Mammetti *et al.* (2024) investigate only linear relationships between the green transition and debt, without considering potential threshold effects of the green transition on debt in EU countries. This clearly highlights the contribution of this study and the gap it aims to fill by examining the impact of the green transition on EU countries' public debt, as these countries are undertaking large-scale green transition initiatives to achieve carbon neutrality by 2050. EU countries are investing heavily in the green transition to boost green technology and develop sustainable industry and transport, contributing to sustainable economic growth. Yet, the rising public debt levels in EU countries raise concerns about whether aggressive green transition efforts influence the extent of public debt. Hypothetically, this study hypothesizes that the green transition has a significant impact on public debt. Therefore, the contribution of this study lies in two forms: (1) it investigates how the green transition influences public debt in EU countries, and (2) it explores the threshold level of green transition at which the transition may shift from being fiscally beneficial to fiscally burdensome. Overall, this study gives a significant conceptual contribution by demonstrating that the fiscal implications of the green transition are not linear but exhibit non-linear dynamics, even though it does not propose a new conceptual framework. These two key findings of the study offer valuable insights for EU policymakers in understanding the impact of the green transition on public debt and in identifying the benchmark level at which green transition efforts remain beneficial before becoming a fiscal burden. Thus, the findings suggest that achieving the climate goals of EU countries requires not only increasing green investment but also careful consideration of fiscal implications to ensure debt sustainability.

3. DATA AND MODEL

In this study, we employed a balanced sample of 27 European countries, including Belgium, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, and the United Kingdom. The dependent and independent variables were collected for the period 2019 to 2024 from two main sources: the World Economic Forum (2024) and the International Monetary Fund (2024). Table no. 2 displays the variable, symbol, and source. The dependent variable, public debt, is measured as public debt (% of GDP), while the independent variables of savings, trade, government expenditure, green transition, and interest rate are measured by gross domestic savings (% of GDP), merchandise trade (% of GDP), government spending (% of revenue), green growth index, and interest payments

(% of revenue), respectively. The explanatory and dependent variables are selected based on three theoretical frameworks – the Two-Gap Model, Keynesian economic theory, and Classical economic theory – as illustrated in Figure no. 3.

Table no. 2 – Variables with symbol, description and sources

| Variables	Symbol	Description	Sources
Public debt	*PB*	Public debt (% of GDP)	
Savings	*SAV*	Gross domestic savings (% of GDP)	
Trade	*TR*	Merchandise trade (% of GDP)	World Economic Forum (2024)
Government spending	*GE*	Government spending (% of revenue)	
Interest rate	*IR*	Interest payments (% of revenue)	
Green transition	*GT*	Green growth index	International Monetary Fund (2024)

Source: author's own illustration

Table no. 3 displays the summary statistics, including the mean, standard deviation, minimum, and maximum values.

Table no. 3 – Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
PB	47.369	1.060	15.700	58.777
SAV	3.405	1.201	1.771	5.323
TR	44.669	0.941	23.026	84.495
GE	2.058	1.088	6.079	15.402
IR	25.917	1.093	16.787	44.158
GT	15.580	0.618	21.333	71.485

Source: author's own illustration

The average value of public debt is 47.369, with minimum and maximum values of 15.700 and 58.777, respectively, for all 27 EU countries. For the green transition, the average value is recorded as 15.580, with the highest and lowest values represented by the United Kingdom and Finland. The highest percentage of interest payments was recorded for Denmark in 2010, whereas the highest percentage of government expenditure is 15.402 in Romania in 1997. Additionally, Figure no. 4 presents the correlation coefficients for the variables. Given the nature of macroeconomic variables, a correlation between government spending, trade openness, and savings is expected. To determine potential multicollinearity, this study first performed a correlation analysis (see Figure no. 4). The correlation matrix indicates a negative correlation between interest rate and savings on public debt, whereas government expenditure, green transition, and trade are positively correlated with public debt. Increases in government expenditure, green transition efforts, and trade are associated with rising public debt.
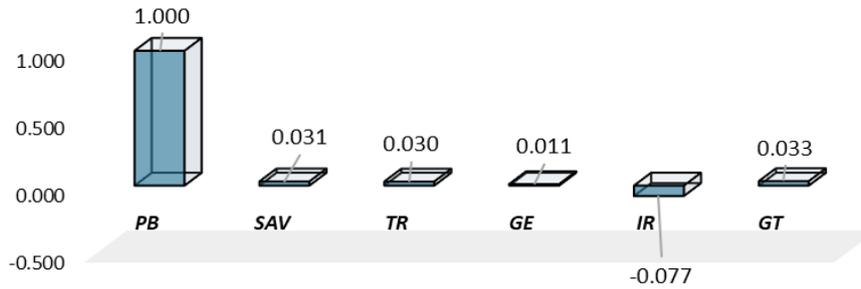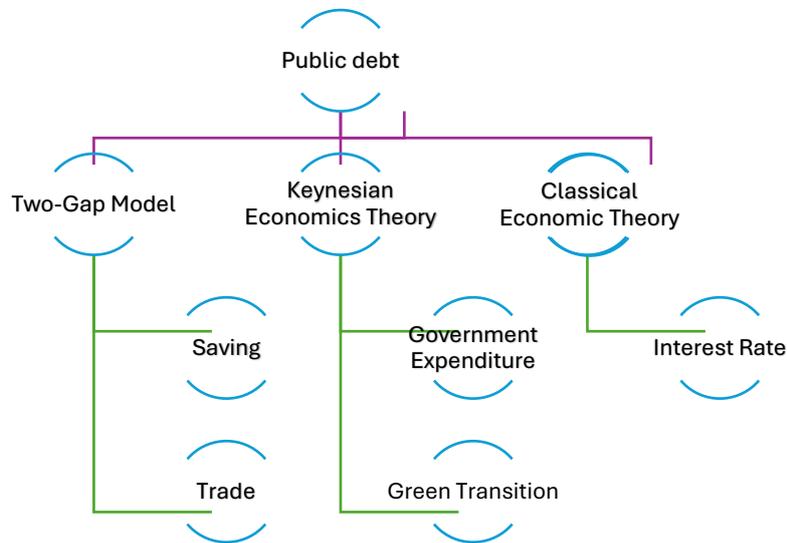
Source: author's own illustration

Figure no. 4 – Correlation analysis

Model

Considering the discussion in the literature review, this study develops a framework based on three theories: the Two-Gap Model, Keynesian Economics Theory, and Classical Economic Theory. As shown in Figure no. 5, the framework illustrates the connection between public debt and the five explanatory variables of savings, trade, government expenditure, interest rate, and, most notably, green transition (Chenery and Strout, 1966; Witt, 1997; Elmendorf and Mankiw, 1999; Salsman, 2017). The Classical Theory highlights that interest rates have a significant impact on the level of debt, while the Two-Gap Model argues that trade and savings contribute to the need for borrowing. Government expenditure and green transition are derived from Keynesian Economics Theory, where an increase in spending and investment in the green transition stimulates economic growth but also influences the level of public debt.

Source: author's own illustration

Figure no. 5 – Framework relating public debt and explanatory variables

Accordingly, this study specified the public debt function as follows

$$lnPB_{it} = \alpha_0 + \beta_1 lnSAV_{it} + \beta_2 lnTR_{it} + \beta_3 lnGE_{it} + \beta_4 lnIR_{it} + \beta_5 lnGT_{it} + \varepsilon_{it} \quad (1)$$

where PB is public debt, SAV is savings, and TR is trade, while GE, IR, and GT stand for government expenditure, interest rate, and green transition, respectively. The subscripts i and t represent country and year, respectively; the prefix ln denotes natural logarithms, and ε is the error term.

In this study, we employ a dynamic panel data approach of Generalized Method of Moments (GMM) panel to explore the impact of the green transition on public debt. Eq. (1) is modified into a dynamic panel estimation model in the following form:

$$lnPB_{it} = \alpha_0 + \gamma lnPB_{it-1} + \beta_1 lnSAV_{it} + \beta_2 lnTR_{it} + \beta_3 lnGE_{it} + \beta_4 lnIR_{it} + \beta_5 lnGT_{it} + \varepsilon_{it} \quad (2)$$

The GMM estimation technique is chosen for its capability to address potential endogeneity problems and because it is the most suitable estimation technique for small panel data structures. Arellano and Bover (1995) and Blundell and Bond (1998) explained that the lagged dependent variable of public debt used as a instruments for address endogeneity problem. Initially, first difference GMM (DIFF-GMM) applied to wipe out the country specific effect under the condition that the disturbance term is not serially correlated with the level of explanatory variables (Arellano and Bond, 1991). Unexpectedly, the correlation between the disturbance term and the lagged difference in the dependent variable may lead to endogeneity of the explanatory variables. So, to overcome this issue, DIFF-GMM combined with an estimator in levels to produce a system GMM (SYS-GMM). As a result, we employ System GMM (SYS-GMM) in this study, which was suggested to be more reliable than first-difference GMM by Arellano and Bond in 1991 (Arellano and Bond, 1991; Blundell and Bond, 1998). There are two statistics, including the serial correlation and Sargan tests, used to validate the GMM estimation. In the Hansen test, which is used to verify the instruments, the number of countries should be greater than the number of instruments. The serial correlation test assumes that the errors do not exhibit serial correlation.

Moreover, this study aims to explore the threshold levels of the green transition. Eq. (2) is extended using Kremer *et al.* (2013)'s dynamic panel threshold regression in the following form:

$$lnPB_{it} = \alpha_0 + \beta_1 lnSAV_{it} + \beta_2 lnTR_{it} + \beta_3 lnGE_{it} + \beta_4 lnIR_{it} + \beta_5 lnGT_{it} I(lnGT_{it} \leq \lambda) \\ + \delta_1 I(lnGT_{it} \leq \lambda) + \beta_6 lnGT_{it} I(lnGT_{it} > \lambda) + \varepsilon_{it} \quad (3)$$

The threshold variable of green transition (GT) is used to split the sample into regimes, where λ is the unknown parameter and I(.) denotes an indicator function. Hence, this threshold regression allows the role of green transition to differ depending on whether GT is below or above the unknown level of λ. According to Caner and Hansen (2004), there are three steps involved in estimating the specific coefficients. First, fitted values are obtained using the ordinary least squares (OLS) technique to estimate a reduced-form regression for the endogenous variables. Second, the threshold parameter is estimated using OLS by substituting the predicted values, and the corresponding sum of squared residuals is computed. Third, the threshold value estimator is chosen as the one that minimizes the sum of squared residuals. The critical values for constructing the 95% confidence interval of the threshold value are provided by Caner and Hansen (2004) as follows: $\Gamma = \lambda: LR(\lambda) \leq C(\alpha)$, where $C(\alpha)$ denotes 95%

percentile of the asymptotic distribution of likelihood ratio statistic $LR(\lambda)$. The number of time periods employed for each cross-section is considered when adjusting the underlying likelihood ratio. Once the threshold value (k) is established, the slope coefficients are estimated using the generalized method of moments (GMM). Following Arellano and Bover (1995) and Kremer *et al.* (2013), lags of the dependent variable are employed as instruments.

4. RESULTS AND DISCUSSION

Prior to evaluating how explanatory variables influence public debt, the GMM model must be validated using the two specification tests of serial correlation and Sargan. The p-value of the Sargan test is 37.75, suggesting that we do not reject the null hypothesis of no over-identifying restrictions (see Table no. 4). The serial correlation test rejects the null hypothesis of no first-order autocorrelation of AR (1) and fails to reject the null hypothesis of no second-order autocorrelation of AR (2). Hence, these two specification tests confirm the validity of the GMM model and indicate that the model specification is reliable. The best estimates between DIFF-GMM and SYS-GMM were chosen using the Difference-Hansen statistic. The discussion that follows will be based on SYS-GMM estimates, as, in light of the Difference-Hansen statistic, they are more accurate and reasonable than DIFF-GMM calculations. Besides that, the lagged dependent variable of public debt is statistically significant at the 5 percent level, meaning that the level of debt in the present period is positively correlated with the level of public debt in the previous year. This implies that the level of debt in the current period increases as the level of debt in the previous year rises.

Table no. 4 – The dynamic GMM panel estimation analysis

	One-Step		Two-Step	
	DIFF-GMM	**SYS-GMM**	**DIFF-GMM**	**SYS-GMM**
lnSAV -	-0.068*	-0.021*	-0.086**	-0.059*
	(0.090)	(0.073)	(0.016)	(0.094)
lnTR -	-0.076**	-0.019**	-0.118**	-0.026 **
	(0.025)	(0.038)	(0.011)	(0.043)
lnGE +	0.052***	0.013**	0.016*	0.040***
	(0.005)	(0.033)	(0.057)	(0.002)
lnIR +	0.094**	0.067**	0.124**	0.011 **
	(0.024)	(0.024)	(0.039)	(0.013)
lnGT +	0.041**	0.027*	0.183*	0.089**
	(0.013)	(0.072)	(0.087)	(0.027)
lnPB$_{t-1}$	0.495***	0.980**	0.493***	0.971**
	(0.000)	(0.031)	(0.000)	(0.036)
Diagnostic Tests				
No. Observations	162	162	162	162
No. Countries	27	27	27	27
Sargan Test	32.82***	89.34**	39.05**	37.75**
	(0.012)	(0.016)	(0.015)	(0.016)
Arellano -Bond test AR (1)	3.46***	4.15 ***	2.79***	4.16*
	(0.001)	(0.000)	(0.005)	(0.000)
Arellano -Bond test AR (2)	1.44	1.13	1.29	1.18
	(0.150)	(0.257)	(0.195)	(0.238)
Difference-Hansen			0.909	0.989

Note: Asterisks *, **, and*** denote the 10%, 5%, and 1% levels of significance, respectively. Figures in ( ) stand p-values.

According to Table no. 4, the coefficient of savings is 0.059 and statistically significant at the 10 percent level. The negative value of the savings coefficient implies that a one percent increase in savings is associated with a 0.059 percent reduction in public debt. This suggests that higher savings help reduce reliance on borrowing and enable the government to finance its expenditures with internal funds without the need for external financing. Consequently, lowering the need for external funds reduces the accumulation of debt burdens. The negative impact of savings on debt is aligned with the findings of prior studies by Imbeau (2004), Swaray (2005), Kirui (2017), and Musah (2023).

The statistically significant negative coefficient for trade is -0.026, implying that an increase in trade lessens the extent of debt in EU countries. Statistically, a 1 percent rise in trade is linked with a -0.026 percent reduction in debt levels. The negative impact of trade is contrary to this study's hypothesis and past studies by Swaray (2005) for less developed countries, Kirui (2017) for Kenya, Omrane Belguith and Omrane (2017) for Tunisia, and Musah (2023) for Ghana. The main reason for this negative influence of trade on debt is mainly due to trade surplus, where the EU countries' volume of exports exceeds the volume of imports. This generates more revenue and foreign exchange earnings, strengthening the fiscal position of EU countries and lessening the need for borrowing, thus reducing debt accumulation. As a result, this study signifies that expansion in trade due to export growth reduces debt levels.

Moreover, government expenditure is statistically significant at the 1 percent level and is positively connected with public debt in EU countries. The coefficient for government expenditure is 0.040, meaning that a 1 percent rise in government expenditure significantly increases the debt level by 0.040 percent. Although government expenditure stimulates economic growth, it also contributes to higher accumulation of debt due to reliance on borrowing to finance these expenditures when revenues are insufficient. The positive influence of government expenditure on debt is also supported by Asiama *et al.* (2014), Frimpong and Oteng-Abayie (2006), Owusu-Nantwi and Erickson (2016), Obeng and Sakyi (2017), and Swamy (2015).

Regarding the impact of interest rates, the results show a positive coefficient of 0.011, which is statistically significant at the 5 percent level. This denotes that a 1 percent increase in the interest rate leads to a 0.011 percent increase in debt levels. Similarly, this positive influence on debt has been identified by Omrane Belguith and Omrane (2017), Kirui (2017), Mupunga and Roux (2015), signifying that rising interest costs can quickly escalate fiscal vulnerability and accumulate debt levels. The cost of governments repaying their current debt increases when interest rates rise. This affects the budget and reduces funds available for other necessary expenditures, thereby possibly forcing governments to borrow even more to pay off their debt and cover spending. In turn, public debt levels further rise.

Predominantly, the core variable of green transition is statistically significant and has a positive impact on the EU's debt levels. This implies that a one percent increase in green transition leads to a 0.089 percent increase in debt. Despite the fact that the green transition helps the EU progress toward climate neutrality by 2050, it requires significant upfront investment for climate adaptation measures, including upgrades to energy efficiency, renewable energy infrastructure, and sustainable transportation. As a result, public debt levels rise. The positive effects of the green transition contradict the findings of Taghizadeh-Hesary and Rasoulinezhad (2025), who discovered that green investment reduces debt in developing countries. This is because developing countries tend to rely on smaller, less capital-intensive

green initiatives, unlike the large-scale, highly capital-intensive green projects undertaken in EU countries. Hence, the green transition increases the public debt levels of EU countries.

Even though the green transition has resulted in increased public debt, this does not mean that EU nations must abandon their green transition initiatives. EU countries must accelerate their green transition efforts to meet the 2050 carbon neutrality target and set an example for other countries. Thus, this study conducted a threshold analysis to determine the green transition threshold, identifying the level at which the green transition shifts from being beneficial to burdensome. Table no. 5 shows the dynamic panel threshold findings, revealing that the threshold value is 5.552 indicates the turning point in the impact of green transition on public debt. Below 5.522, the impact of the green transition is significantly negative, while the impact turns positive above the threshold of 5.552. This provides empirical evidence that a higher green transition above the threshold value contributes to fiscal pressures and higher debt burdens in EU countries. Green transition investment is becoming more productive and efficient and exhibits beneficial impacts on economic sustainability, but the high capital intensity and upfront investments made in accordance with EU climate targets continue to increase EU debt levels. As a result, the threshold analysis shows that only green transitions beyond the threshold level continue to increase public debt in EU countries. For the other control variables, the impact of savings, trade, government expenditure, and interest rates is similar to the results obtained from the earlier estimations shown in Table 3. Savings and trade negatively impact debt levels, while interest rates and government expenditure positively impact debt levels in EU countries.

Table no. 5 – Dynamic panel threshold regression analysis

Threshold	**5.552**
Confidence interval	[0 .223-10.882]
Impact of GT	
β_5	-0.064** (0.021)
β_6	0.044** (0.028)
Impact of covariates	
lnSAV -	-0.183* (0.09)
lnTR -	-0.047** (0.037)
lnGE +	0.020* (0.082)
lnIR +	0.033** (0.029)
δ_1	0.276** (0.018)
Observation	162

Note: Asterisks *, **, and*** denote the 10%, 5%, and 1% levels of significance, respectively. Figures in ( ) stand p-values.

In this study, an additional robustness check conducted by applied alternative estimation technique of Ordinary Least Squares (OLS) and two-stage least squares (2SLS) to check the sensitivity of the main findings. The results are reported in Table no. 6. Empirically, the results

from these two estimations of OLS and 2SLS like earlier results presented in Table no. 4. This provides significant and sound support to the earlier conclusion that the green transition is associated with a high level of debt in EU countries. Green transitions, including investments in renewable energy, green infrastructure, energy efficiency, and climate adaptation, are capital-intensive, which can increase budget deficits and public debt. Additionally, the other controlled variables yield the same results as discussed above.

Table no. 6 – The dynamic GMM panel estimation analysis

	OLS	2SLS
lnSAV -	-0.045**	-0.029**
	(0.027)	(0.025)
lnTR -	-0.019*	-0.070**
	(0.051)	(0.042)
lnGE +	0.025***	0.014**
	(0.032)	(0.023)
lnIR +	0.033***	0.029**
	(0.019)	(0.033)
lnGT +	0.026*	0.058**
	(0.059)	(0.022)
Model criteria		
No. Observations	162	162
No. Countries	27	27
R^2	0.750	0.838
F-statistics	3.130***	2.180***
	(0.000)	(0.005)

Note: Asterisks *, **, and*** denote the 10%, 5%, and 1% levels of significance, respectively. Figures in ( ) stand p-values.

5. CONCLUSION

This study examines the impact of green transition on public debt in European Union countries over the period 2019–2024 using GMM estimation. The empirical evidence reveal that the green transition is associated with higher public debt levels, reflecting the fiscal burden arising from high upfront investment costs, delayed economic returns, and implementation inefficiencies. More essentially, the threshold analysis based on Kremer et al. (2013) reveals a non-linear relationship, showing that green transition begins to exert an adverse effect on public debt once a critical threshold is exceeded. These findings contribute theoretically by extending the green finance and public debt literature beyond linear assumptions, highlighting that the fiscal impact of the green transition depends on its scale and intensity. Empirically, this study offers novel evidence from the EU context, demonstrating that even advanced economies with strong environmental commitments face debt sustainability challenges when green investments expand beyond fiscally manageable levels. These findings underscore the importance of carefully sequencing and financing green transition policies to balance environmental objectives with long-term fiscal sustainability.

EU countries are recommended to undertake sustainable and balanced green transition investments to prevent debt pressure, as the green transition is linked to an increase in public debt above certain thresholds. Governments need to prioritize cost-effective green initiatives, the efficient distribution of green funds, and the expansion of private sector financing through

public-private partnerships to share the investment and lessen the debt burden. For instance, EU governments and policymakers should prioritise funding less costly and small-scale green projects rather than expensive large-scale projects, as these can more effectively reduce operating costs. Meanwhile, expensive large-scale green projects should be postponed or financed through EU grants or private funding. An efficient distribution of green funds should be targeted at specific economic sectors rather than being widely dispersed, and green funding should be limited to productive investments with a defined time period, with funding discontinued if targets are not met. This helps EU countries avoid unnecessary increases in public debt. Moreover, EU policymakers and governments should increase the role of the private sector in financing green infrastructure, such as renewable energy, electric vehicles, and power grids, through public–private partnerships. Additionally, EU authorities need to enhance accountability, transparency, and institutional coordination in implementing green transition projects. This helps ensure that public funds are used efficiently, promotes private sector engagement, and reduces reliance on debt-financed public spending.

This study has some limitations. Firstly, it employs public debt as a percentage of GDP as the sole measure of debt, which may not capture the broader fiscal impact of green transitions. Secondly, the analysis is limited to EU countries, which may constrain the generalizability of the findings, and employs short panel data due to data availability. Future research could explore the effects of the green transition using total debt indicators, extend the scope to include non-EU countries, and use longer time periods to achieve a more comprehensive understanding.

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Notes

[1] Public debt in the European Union is shaped by multiple factors, including macroeconomic conditions, fiscal responses to economic crises, demographic pressures, interest rate movements, and structural public expenditures. Hence, not all public debt can be attributed to green transition initiatives. In this study, we do not assume that the green transition is the sole driver of public debt; rather, we examine whether green transition efforts constitute a significant contributing factor to public debt in the EU. Specifically, the analysis focuses on the marginal and potentially non-linear impact of green transition intensity on public debt, while controlling for other macroeconomic influences.