Afonso, António; Alves, José; Ferrara, Alessio; Monteiro, Sofia

Working Paper

Green Fiscal Multipliers with Different Sovereign Debt Trajectories in EU Countries

CESifo Working Paper, No. 12039

Provided in Cooperation with:
Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

Suggested Citation: Afonso, António; Alves, José; Ferrara, Alessio; Monteiro, Sofia (2025) : Green Fiscal Multipliers with Different Sovereign Debt Trajectories in EU Countries, CESifo Working Paper, No. 12039, CESifo GmbH, Munich

This Version is available at:
https://hdl.handle.net/10419/325030

CES ifo Working Papers

12039
2025

July 2025

Green Fiscal Multipliers with Different Sovereign Debt Trajectories in EU Countries

António Afonso, José Alves, Alessio Ferrara, Sofia Monteiro

CES ifo

Imprint:

CESifo Working Papers

ISSN 2364-1428 (digital)

Publisher and distributor: Munich Society for the Promotion
of Economic Research - CESifo GmbH

Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740

Email office@cesifo.de
https://www.cesifo.org

Editor: Clemens Fuest

An electronic version of the paper may be downloaded free of charge
· from the CESifo website: www.ifo.de/en/cesifo/publications/cesifo-working-papers
· from the SSRN website: www.ssrn.com/index.cfm/en/cesifo/
· from the RePEc website: https://ideas.repec.org/s/ces/ceswps.html

Green Fiscal Multipliers with Different Sovereign Debt Trajectories in EU Countries*

Antonio Afonso† Jose Alves‡ Alessio Ferraro§
Sofia Monteiro¶

July 29, 2025

Abstract

This paper estimates the fiscal multipliers of green public spending using a linear Bayesian Panel VAR and a Smooth Transition VAR framework, with quarterly data for the period 1995Q1–2022Q4 for EU member states. We group EU member states based on similarities in debt trajectories and green spending intensity, forming three regional aggregates: Southern Europe, Eastern Europe, and Northern Europe. Our results show that green spending multipliers on GDP are generally below one, but the response of private investment is significantly stronger — particularly in Southern and Eastern Europe. Multipliers tend to be larger in periods of high public debt, suggesting that green fiscal expansions may be more effective during downturns. Another key finding is that in response to green spending shocks, both long-term interest rates and public debt tend to decline—especially in high-debt regimes—indicating improved market expectations about fiscal sustainability. In contrast, when we estimate the effects of a shock to total public spending net of green spending, we find that both interest rates and debt increase. This suggests that economic agents perceive green spending more favorably than undifferentiated fiscal expansions, likely due to its role in mitigating climate risks, lowering long-term energy costs, and signaling credible long-term policy commitments.

Keywords:green fiscal multipliers; debt trajectories; interest rates; Bayesian Panel Vector Autoregression (BVAR)
JEL codes:C23; E44; E62; G15; H62; H63

*This work was supported by the FCT (Fundação para a Ciência e a Tecnologia) [grant number UIDB/05069/2020]. The opinions expressed herein are those of the authors and do not necessarily reflect those of the authors' employers. Any remaining errors are the authors' sole responsibility.

†ISEG – Lisbon School of Economics and Management, Universidade de Lisboa; REM – Research in Economics and Mathematics, UECE. Email: aafonso@iseg.lisboa.pt

‡ISEG – Lisbon School of Economics and Management; REM – UECE. Email: jalves@iseg.ulisboa.pt

§University Roma Tre. Email: alessio.ferraro@uniroma3.it

¶ISEG – Lisbon School of Economics and Management; REM – UECE. Email: asmonteiro@iseg.ulisboa.pt

1 Introduction

To meet the goals of the Paris Agreement (Agreement, 2015), a significant acceleration of decarbonisation will be necessary, requiring an increase in green infrastructure investment of around 2 percent of global GDP per year, according to the International Energy Agency. A substantial share of this investment will need to come from the public sector, putting governments in a difficult position as they balance the need to restore fiscal health after the large budget deficits incurred during the pandemic with the urgency of scaling up green spending. This trade-off is particularly evident in the European Union, which has positioned itself as a global leader in climate action. To meet its climate objectives, the EU will need to increase public investment by approximately 0.6 percent of GDP annually throughout this decade—a figure that could rise if the green transition is accelerated, for instance in response to Russia's invasion of Ukraine. A gradual fiscal consolidation appears feasible if EU fiscal rules are interpreted flexibly. However, past experiences show that fiscal tightening has often resulted in significant cuts to public investment. The objective of this paper is to estimate the fiscal multipliers of green public spending, taking into account the critical role played by public debt levels. Specifically, we examine the effects of exogenous green spending shocks under two distinct fiscal regimes: one characterized by high public debt ratios and the other by low public debt ratios. This framework allows us to assess whether the effectiveness of green fiscal policy depends on the available fiscal space. Hence, we estimate the fiscal multipliers of green public spending using a Bayesian Panel VAR with linear and smooth transition specifications. Instead of focusing on individual countries, we group EU member states based on similarities in public debt ratios trajectories and green spending intensity. Specifically, we distinguish three regional groups for the linear VAR: Southern Europe (Italy, Spain, Portugal, Greece, France, Belgium), Eastern Europe (Poland, Hungary, Czech Republic, Slovenia, Slovakia, Romania), and Northern Europe (Germany, Austria, Netherlands, Denmark, Sweden, Finland). For the smooth transition VAR, we estimate two models: one for 12 euro area countries and another for the full sample of 18 EU countries.

Fiscal shocks are identified using a Cholesky decomposition, with green spending ordered first. Fiscal multipliers are computed following Ramey and Zubairy (2018), using cumulative responses over the entire horizon. This approach, in the spirit of Mountford and Uhlig (2009) , calculates multipliers as the ratio of the integral of output responses to the integral of government spending, and allows for a more comprehensive assessment of the dynamic effects.

Our results show that green fiscal multipliers are consistently below one across both linear and non-linear models. However, public debt and long-term interest rates tend to decline in response to green spending shocks, indicating improved market expectations regarding fiscal sustainability. The decline in interest rates is more pronounced in high-debt regimes, in line with Auerbach and Gorodnichenko (2017), who argue that fiscal policy can remain effective as long as interest rates do not react adversely to the stimulus. Our results also show that the multipliers associated with private investment, while remaining modest in absolute terms, are significantly higher than those of public green spending: approximately 0.60 compared to 0.30. This suggests that private investment triggered by the green transition—if appropriately incentivized—may represent a relatively more effective channel to support economic growth. As a robustness check, we estimate the effects of a shock to total public spending net of green spending. In this case, we find that although multipliers are slightly larger, both debt and interest rates increase, suggesting that economic agents and financial markets perceive green spending differently from undifferentiated public expenditure. Therefore, financial markets do not increase the risk premium in response to green spending, likely because it:

- mitigates future climate-related risks,
- reduces energy dependence and long-term energy costs,
- supports innovation and long-term productivity,
- signals a credible and sustainable fiscal strategy aligned with climate commitments.

Thus the goal is to assess whether green public policies are fiscally sustainable, or whether a different policy design is required—potentially involving greater reliance on regulatory measures or the adoption of instruments such as golden rules, as suggested by Darvas and Wolff (2021). The results of this study show that the fiscal multipliers of green public spending remain below one in both the linear and nonlinear models. However, this primarily reflects the still limited scale of green investment, as highlighted by Sadler et al. (2024) , rather than any inherent inefficiency of green spending itself.

A particularly noteworthy finding is that green spending shocks are systematically associated with a decline in long-term interest rates, in stark contrast to the effects of aggregate public spending. This pattern can be interpreted as a signal of market confidence in the macro-fiscal trajectory, suggesting that green spending not only avoids financial crowding-out, but may actually help improve the intertemporal profile of public finances. Moreover, the interest rate response reflects the ability of green spending to generate expected future benefits, in terms of productivity, energy security, and a reduction in systemic risks associated with climate change.

While regulatory instruments remain essential—as emphasized byDarvas and Wolff (2021) —these findings suggest that spending and investment policies must also play a central role in the green transition. In light of our evidence, an effective climate strategy cannot rely on regulation alone: a sustained and well-designed fiscal effort is needed to scale up green investment and unlock its full macroeconomic potential.In recent years, the literature on fiscal multipliers has highlighted how the effectiveness of fiscal policy crucially depends on the macroeconomic context. Romer and Romer (2010) and Auerbach and Gorodnichenko (2012) show that multipliers tend to be higher during recessions, while studies such as Afonso and Sousa (2012) and Ilzetzki et al. (2013) emphasize that high levels of public debt can weaken the impact of fiscal stimulus. An emerging strand of research focuses on "green" public investment and spending, analyzing their potential to deliver both expansionary and sustainable outcomes.Batini et al. (2022) find that green fiscal interventions can have high multipliers, especially when there is slack in the economy. Similarly,(Ciaffi, 2025) shows that environment spending can boost growth, innovation, and social cohesion, contributing to an effective ecological transition. This paper contributes to this literature by analyzing the effectiveness of green fiscal multipliers under different public debt conditions.The paper is structured as follows: Section 2 is the literature reviews on fiscal multipliers, with a focus on green spending. Section 3 describes the data and methodology. Section 4 presents the results of the linear Bayesian VAR and the linear fiscal multipliers. Section 5 reports the smooth transition Bayesian panel VAR and non-linear fiscal multipliers results. Section 6 provides robustness analysis for green spending vs total public spending. Section 7 is the conclusions .

2 Literature

The literature on fiscal multipliers has grown substantially since the 2008–2009 Global Financial Crisis (GFC), with a central focus on identifying the macroeconomic conditions under which fiscal policy is most effective. A key finding from this body of work is that fiscal multipliers are not constant: they vary depending on the state of the economy, the type of fiscal intervention, the level of public debt, and expectations about future policy.

Auerbach and Gorodnichenko (2012) provide evidence that multipliers are significantly higher during recessions than expansions, using a regime-switching model that captures the state-dependence of fiscal effects. Their results suggest that fiscal stimulus can be particularly effective when output is below potential and monetary policy is constrained. However, this view is challenged by Ramey and Zubairy (2018), who, using historical U.S. data, find that multipliers do not systematically increase during periods of high unemployment. These contrasting results highlight the sensitivity of fiscal multiplier estimates to model specification and identification strategy.

Another important strand of the literature examines how fiscal multipliers vary with public debt

levels.Ilzetzki et al. (2013) and Huidrom et al. (2020) find that high debt levels tend to reduce the effectiveness of fiscal policy, due to expectations of future consolidation (the Ricardian channel) and increases in sovereign risk premiums.Auerbach and Gorodnichenko (2017) argue, however, that even under high debt, fiscal stimulus can still be effective, especially when real interest rates are low. These findings underscore the importance of fiscal space as a constraint on discretionary fiscal action.

More recent research has shifted attention to the composition of fiscal spending. Several studies—including Deleidi et al. (2020) and Saccone et al. (2022)—highlight that public investment, especially in infrastructure and human capital, tends to produce larger and more persistent output effects than current or transfer spending. This has led to renewed interest in investment-led fiscal policy, particularly in the context of the post-pandemic recovery and climate transition.

Within this broader framework, a growing body of literature focuses on the macroeconomic effects of green public spending. Batini et al. (2022) offer one of the first systematic evaluations of green fiscal multipliers, showing that investments in low-carbon infrastructure, renewable energy, and biodiversity yield multipliers ranging between 1.1 and 1.7—substantially higher than those associated with fossil fuel-intensive projects. Their findings are based on cross-country data and highlight that green investments are not only environmentally necessary but also economically efficient, particularly in times of economic slack.

Similarly, Ciaffi (2025) analyze the impact of green public spending in Europe, emphasizing the North-South divide. Using a Local Projections framework applied to 30 European countries from 1995 to 2020, they show that green investment spending produces more favorable macroeconomic outcomes than green current expenditures. The expansionary effects are more pronounced in high-income countries, and the study documents positive spillovers on productivity and private investment, supporting the hypothesis that green public investment can initiate self-sustaining growth dynamics. However, the literature still lacks systematic evaluations of how green multipliers interact with fiscal conditions such as public debt levels.

At the subnational level,Ficarra (2024) investigates the heterogeneity of green and non-green spending effects across Italian provinces. By constructing a new dataset of public works between 2013 and 2021, and employing a Local Projections approach, the study shows that green investment tends to have a more positive impact on output than non-green spending, although the effects vary significantly by region and institutional quality. For example, green investment in Northern Italy generates modest but persistent growth, whereas in the South, the initial response is strong but fades quickly. The paper also highlights a surprising result: in contexts of high regulatory burden, corruption may paradoxically increase the fiscal multiplier by circumventing bureaucratic inefficiencies.

Taken together, this literature points to several gaps that our work seeks to address. First, while the macroeconomic effectiveness of green public investment is increasingly recognized, little is known about how this effectiveness varies under different public debt regimes. Second, most studies estimate average multipliers without accounting for nonlinearities induced by fiscal space constraints or shifts in debt dynamics. Third, the identification of exogenous green fiscal shocks remains challenging, with few studies employing narrative or structural approaches.

Our study contributes to the limited literature on green fiscal multipliers by examining how public debt levels influence their magnitude and how debt and interest rates respond to green fiscal shocks. Unlike studies relying on narrative identification or local projections, our empirical strategy is based on a Bayesian Panel VAR model, where fiscal shocks are identified using a Cholesky decomposition, ordering green spending first. This allows us to isolate the exogenous impact of green public spending on the economy.

3 Data

This study uses data from the Environmental Protection Expenditure Accounts (EPEA) of the European Commission, which measure the economic resources allocated by households, firms, and governments to environmental protection activities—such as pollution abatement, waste and wastewater management, biodiversity conservation, *RD*, and education. Structured by institutional sector and environmental domain (based on the CEPA 2000 classification), the EPEA captures both public and private environmental services provision.

Environmental protection expenditure reflects the total resources used within a country to safeguard the environment, and includes current and capital spending, as well as net transfers abroad. According to Eurostat, total EU environmental protection expenditure—measured by National Expenditure on Environmental Protection (NEEP)—rose by 27 percent between 2018 and 2023 (see figures Appendix A), though its share of GDP remained relatively stable, fluctuating between 2 percent and 2.2 percent. Over the same period, investment in environmental protection rose by 28 percent, with a 22 percent increase recorded between 2020 and 2023, after the temporary drop caused by the COVID-19 crisis.

In 2023, NEEP reached €357 billion in the EU, tracking GDP growth and keeping the NEEP-to-GDP ratio stable at around 2.1–2.2 percent. The business sector accounted for 52 percent of NEEP, including both specialist producers and firms managing environmental activities in-house. Between 2018 and 2023, business-related environmental spending increased by 33 percent. Public administrations and non-profits contributed 31 percent, and households 17 percent, with public/non-profit spending growing by 33 percent and household spending rising by 6 percent.

There is wide variation in NEEP-to-GDP ratios across EU countries. In 2021, values ranged from 0.9 percent in Ireland and Luxembourg to 3.6 percent in Austria. Eight countries—including Italy, Germany, and Poland—exceeded the EU average of 2.2 percent. The European Green Deal identifies investment as key to delivering environmental goals. In 2023, the EU invested €67 billion in environmental services, mainly in wastewater (41.6 percent) and waste management (26.6 percent), followed by air protection (10.4 percent), biodiversity (6.4 percent), soil protection (5.6 percent), and *RD*, education, and other activities (8.4

Public investment in environmental protection varies substantially across member states—from 0.1 percent to 9.6 percent of total spending—reflecting different institutional arrangements (e.g., public vs. market provision of waste services). Our dataset follows the COFOG classification (Division 5), which includes waste, wastewater, pollution abatement, biodiversity, and related activities. In 2023, total government spending on environmental protection in the EU was 0.8 percent of GDP, with 0.4 percent allocated to waste, and 0.1 percent each to wastewater, pollution, biodiversity, and unclassified services.

Greece and the Netherlands had the highest public green spending (1.5 percent of GDP), followed by Malta and Belgium (1.2 percent) and Luxembourg (1.1 percent). Waste management represented the highest shares in Greece, Netherlands, Bulgaria, and Malta (up to 0.9 percent of GDP), while wastewater management was particularly relevant in Luxembourg, Slovenia, Netherlands, and Cyprus. Greece also led the EU in pollution abatement (0.6 percent of GDP), ahead of Belgium (0.4 percent). Spending on biodiversity remains low across the EU, peaking at 0.2 percent of GDP in Malta, Czechia, Denmark, and Iceland. Public *RD* in environmental protection remains marginal, typically below 0.1 percent of GDP (see Appendix A).

Between 1995 and 2023, general government spending on environmental protection fluctuated between 0.7 percent and 0.8 percent of GDP, and between 1.5 percent and 1.7 percent of total public expenditure. From 2022 to 2023, environmental protection spending rose by €14 billion (+11 percent), from €127 billion to €142 billion, with its GDP share stable at 0.8 percent.

To match the quarterly frequency of the rest of our dataset, annual public expenditure data were interpolated using the Denton method, which preserves annual totals while smoothing higher-frequency variation.

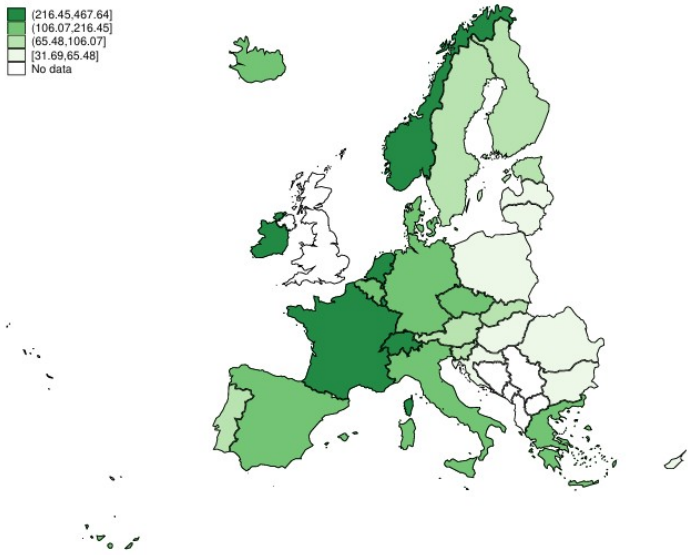


Figure 1: Public Green Spending 1995-2023

In our dataset, the debt-to-GDP ratio from 1995 to 2022 captures the effects of major macroeconomic shocks, notably the 2008 global financial crisis — followed by the sovereign debt crisis within the euro area — and the 2020 COVID-19 pandemic. These events led to significant increases in public debt levels, the trajectory of which is illustrated in the figures presented.As shown in Figure 2,3 and 4, public debt levels in EU countries rose sharply following the 2008 financial crisis, then either stabilized or declined in some cases during the following decade. However, a renewed increase is observed in response to the COVID-19 shock. Debt levels remain structurally higher in Southern European countries, highlighting greater fiscal space constraints in these economies—particularly in the face of green public spending initiatives. Our analysis covers the period from 1995 to 2002 (see Appendix A), using quarterly data. Since the available data on public spending and investment are annual,to obtain quarterly series from annual data, we applied the Denton interpolation method, which preserves the annual totals while minimizing higher-frequency fluctuations. This procedure ensures consistency with officially reported aggregates and improves the temporal resolution of the analysis.We interpolated annual data for green public spending, total public spending net of green spending, and private investment using the Denton method, which ensures consistency with annual aggregates while improving the frequency of the series. Long-term interest rates (10-year government bond yields) were converted from monthly to quarterly frequency through averaging. Public debt was normalized to account for the considerable heterogeneity in debt levels across countries, which would otherwise hinder meaningful cross-country comparisons.Specifically, for each country i and time t, the normalized debt variable is computed as:

$$z\text{-score}_{i,t} = \frac{\text{debt}_{i,t} - \mu_{\text{EU}}}{\sigma_{\text{EU}}} \tag{1}$$

where μ_{eu} and σ_{eu} denote, respectively, the cross-country mean and standard deviation of public debt within the European Union. This normalization accounts for large cross-sectional differences in debt levels and allows for more meaningful comparisons across countries and over time.

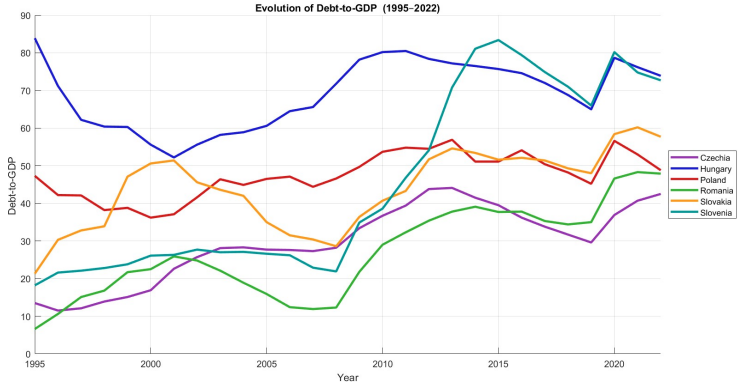


Figure 2: Debt to GDP East European Countries

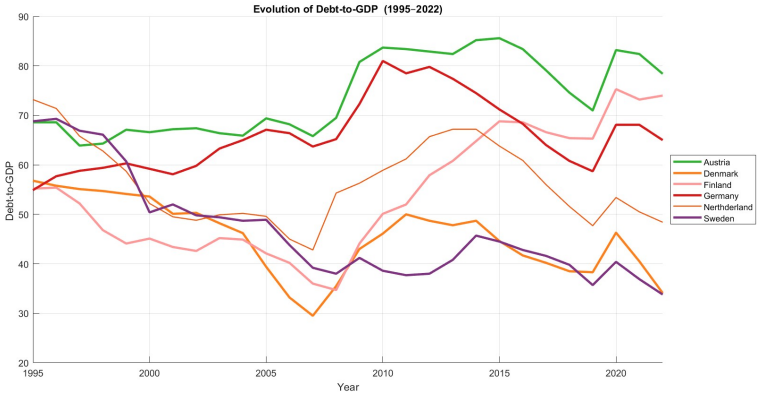


Figure 3: Debt to GDP North European Countries

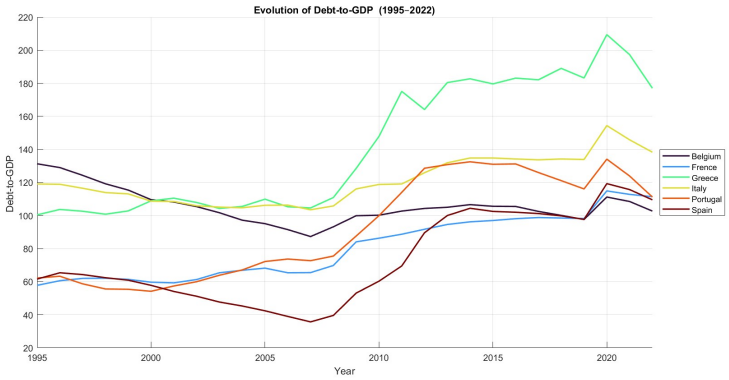


Figure 4: Debt to GDP South European Countries

4 Linear model: Panel Bayesian VAR

In this section, we estimate a linear Panel VAR model by grouping European Union countries into clusters that exhibit similar macroeconomic characteristics, particularly in terms of green public spending and the trajectory of public debt. Accordingly, we divide the panel into three regional blocs:

- Southern Europe: Italy, France, Belgium, Greece, Spain, and Portugal;
- Northern Europe: Germany, Austria, Denmark, Sweden, the Netherlands, and Finland;
- Eastern Europe: Poland, Hungary, Czech Republic, Slovenia, Slovakia, and Romania.

This classification aims to capture potential structural and institutional heterogeneities in the transmission of macroeconomic shocks and ensures greater internal consistency in the estimated dynamics within each group. To analyze the dynamic responses of macroeconomic variables to green public spending shocks across European countries, we estimate a Bayesian Panel Vector Autoregression (BVAR) model with fixed effects. The model includes country- and year-specific dummy variables to account for unobserved heterogeneity and common time shocks. The estimation follows a Minnesota-type prior structure, imposing shrinkage on the lag coefficients to prevent overfitting in high-dimensional systems.

Specifically, we specify a $BVAR$ model with $K = 6$ endogenous variables: public expenditure (gov), green spending (green), interest rate ($interest.rate$), public debt (debt), private investment (investment), and GDP (GDP), ordered to allow for recursive identification of structural shocks via Cholesky decomposition. The model includes $p = 4$ lags and is estimated on quarterly panel data from multiple EU countries over the period 1995Q1–2022Q4.

Priors are set on the coefficients using the standard Minnesota prior, where own-lag coefficients are centered around one and cross-lags around zero, with decay determined by lag length. Fixed effects are included by augmenting the regressor matrix with country and year dummies (excluding the base category), following a "dummy observation" interpretation of the prior.

Posterior inference is conducted via Gibbs sampling with 10,000 iterations and 3,000 burn-ins. At each iteration, we draw from the conditional posterior of the coefficient matrix and the covariance matrix of the residuals, and compute orthogonalized impulse response functions (IRFs) up to a 16-quarter horizon. The structural shock is identified as a one-standard-deviation innovation to green spending, assumed to be the first variable in the Cholesky ordering.

Posterior distributions of the IRFs are summarized using median responses and credible intervals

at the 68 percent and 95 percent levels. The VAR has this form:

$$\mathbf{y}_{i,t} = \sum_{l=1}^{p} \mathbf{A}_l \mathbf{y}_{i,t-l} + \boldsymbol{\alpha}_i + \boldsymbol{\gamma}_t + \boldsymbol{\varepsilon}_{i,t}, \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(0, \boldsymbol{\Sigma}), \tag{2}$$

$\mathbf{y}_{i,t}$ is a $K \times 1$ vector of endogenous variables for country i at time t.

$\mathbf{A}_l$ are the coefficient matrices associated with the l-th lag, for $l = 1, \ldots, p$.

$\boldsymbol{\alpha}_i$ denotes country-specific fixed effects.

$\boldsymbol{\gamma}_t$ denotes time fixed effects (e.g., year dummies).

$\boldsymbol{\varepsilon}_{i,t}$ is the vector of reduced-form residuals, assumed to be normally distributed with covariance matrix $\boldsymbol{\Sigma}$.

To regularize the estimation and incorporate prior beliefs on the dynamic properties of the system, we adopt a Minnesota-type prior on the autoregressive coefficients. This prior assumes that each variable follows a random walk (or near-random walk), while cross-variable dynamics are relatively less informative. Specifically, the prior mean and variance for each autoregressive coefficient $A_{l,jk}$—that is, the effect of the $k-th$ variable at lag l in the equation for variable $j|are$ defined as follows:

$$E[A_{l,jk}] = \begin{cases} 1, & \text{if } j = k \text{ and } l = 1 \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

$$\text{Var}[A_{l,jk}] = \begin{cases} \frac{\lambda^2}{l^\delta}, & \text{if } j = k \\ \frac{\theta^2 \lambda^2}{l^\delta}, & \text{if } j \neq k \end{cases} \tag{4}$$

λ controls the overall tightness of the prior distribution; smaller values imply stronger shrinkage toward the prior mean.

θ governs the relative shrinkage on cross-variable lag coefficients (i.e., when the predictor and the dependent variable differ).

δ determines the rate at which the prior variance decays as the lag order increases, penalizing longer lags more heavily.

(Litterman, 1986; Primiceri et al., 2015)

The shock is identified through a Cholesky decomposition:

$$\boldsymbol{\varepsilon}_{i,t} = \mathbf{P}\mathbf{u}_{i,t}, \quad \mathbf{P}\mathbf{P}^\top = \boldsymbol{\Sigma} \tag{5}$$

$\mathbf{u}_{i,t}$ is a vector of orthogonal structural innovations.

$\mathbf{P}$ is a lower triangular matrix obtained through the Cholesky decomposition of the reduced-form covariance matrix $\boldsymbol{\Sigma}$, such that $\mathbf{P}\mathbf{P}^\top = \boldsymbol{\Sigma}$.

To compute impulse response functions (IRFs), we rewrite the estimated VAR model in its first-order companion form. This allows us to simulate the dynamic effects of a structural shock on the system over time. Let S_t denote the state vector that stacks the current and lagged values of the endogenous variables. The system can then be expressed as:

$$\mathbf{s}_{t+1} = \mathbf{C}\mathbf{s}_t + \mathbf{E}_t, \quad \mathbf{s}_0 = \mathbf{P}\mathbf{e}_j \tag{6}$$

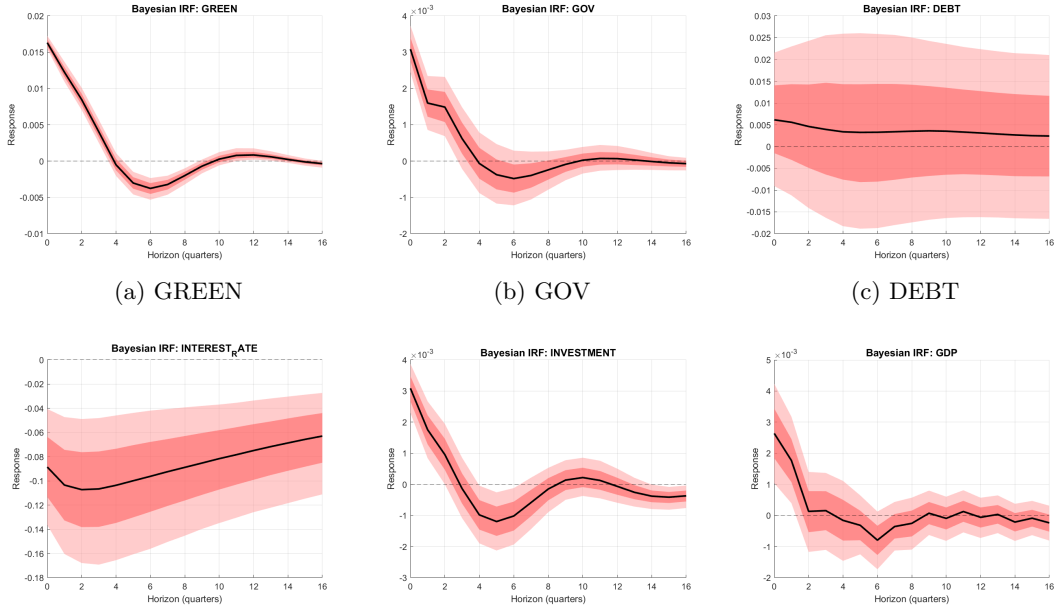
$\mathbf{s}_t$ is the state vector in companion form, stacking current and lagged values of the endogenous variables.

$\mathbf{C}$ is the companion matrix constructed from the set of coefficient matrices $\{\mathbf{A}_l\}_{l=1}^{p}$.

$\mathbf{e}_j$ is a selection vector (unit vector) with 1 in the j-th position and zeros elsewhere, identifying the structural shock to variable j (e.g., green spending).

We begin our empirical analysis by presenting the results from the Bayesian Panel VAR estimated on the group of Northern European countries, which includes Germany, Austria, Denmark, Sweden, the Netherlands, and Finland. These countries are characterized by relatively stable public finances, moderate levels of green public investment, and strong institutional frameworks.

The objective is to assess the dynamic effects of green public spending shocks on key macroeconomic aggregates, such as GDP, private investment, public debt, and interest rates, within a relatively homogeneous institutional and fiscal context. The identification of shocks follows a standard Cholesky decomposition, with green spending ordered first, and the impulse response functions (IRFs) are computed using the companion form representation.



(a) GREEN (b) GOV (c) DEBT

(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 5: IRFs to Green Shock – North European Countries

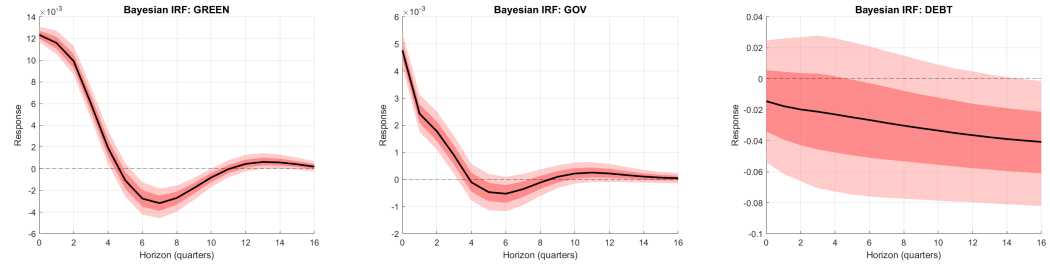
Figure 5 presents the posterior impulse response functions (IRFs) for Northern European Countries following a positive one-standard-deviation shock to green public spending. The IRFs are based on the Bayesian Panel VAR estimates and illustrate the median response alongside the 68 percent and 95 percent credible intervals over a 16-quarter horizon. The shock to green spending itself is transitory, with a strong initial response that decays rapidly and becomes statistically indistinguishable from zero after approximately 6 quarters. The response of total government spending is similarly short-lived, suggesting a limited pass-through from green to broader public spending in this group of countries. Turning to macroeconomic outcomes, GDP and private investment both display a modest but positive response to the shock, particularly between quarters 6 and 10. The response of private investment is more persistent and statistically significant at the 68 percent level over several quarters, indicating a potential crowd-in effect of green fiscal stimulus in Northern Europe. The public debt ratio shows a slight upward drift following the shock, but remains within wide confidence bounds, implying no robust evidence of fiscal deterioration. Finally, the interest rate exhibits a temporary decline, possibly reflecting accommodative monetary policy or limited inflationary pressure in response to green fiscal expansion.

Overall, the results suggest that in Northern Europe, green public spending shocks yield mild expansionary effects with limited fiscal or financial instability, consistent with the region's insti-

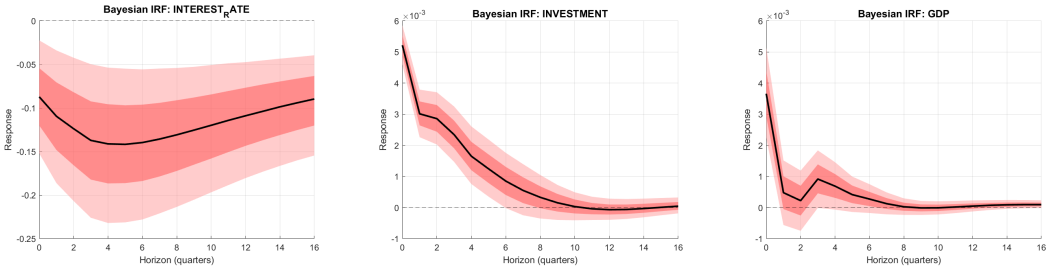
tutional strength and fiscal credibility. We now turn to the results obtained from the Bayesian Panel VAR estimated for Southern European countries, namely Italy, Spain, Portugal, Greece, France, and Belgium. These economies share characteristics such as higher public debt ratios and varying levels of green investment relative to their Northern counterparts. Our goal is to assess whether structural shocks to green public spending have differential macroeconomic effects in this context.

Using the same identification strategy—Cholesky decomposition with green spending ordered first—and impulse response analysis over a 16-quarter horizon, we present posterior median IRFs with 68 percent and 95 percent credible bands.

This section explores the dynamics of aggregate variables—GDP, private investment, public debt, and interest rates—following a green spending shock, highlighting potential asymmetries in transmission relative to Northern European economies.



(a) GREEN (b) GOV (c) DEBT



(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 6: IRFs to Green Shock – South European Countries

Figures 6 present the impulse response functions (IRFs) for Southern European countries (Italy, Spain, Portugal, Greece, France, and Belgium) following a positive shock to green public spending. The responses are derived from a Bayesian Panel VAR model over a 16-quarter horizon and show the posterior median along with 68 percent and 95 percent credible intervals.

Green and total public spending: The initial response of green spending is strong and gradually fades after approximately 8 to 10 quarters. The reaction of total government expenditure mirrors this dynamic, with a positive but temporary increase followed by reversion, likely reflecting fiscal constraints.

GDP: The output response is immediately positive, dips slightly mid-horizon, but remains positive and statistically significant over a longer period compared to Northern Europe. This suggests a more durable and sustained transmission of the green fiscal stimulus to output in the Southern region.

Private investment: The response of private investment is more persistent and stronger than that observed in Northern Europe. The positive impact extends over multiple quarters, indicating a

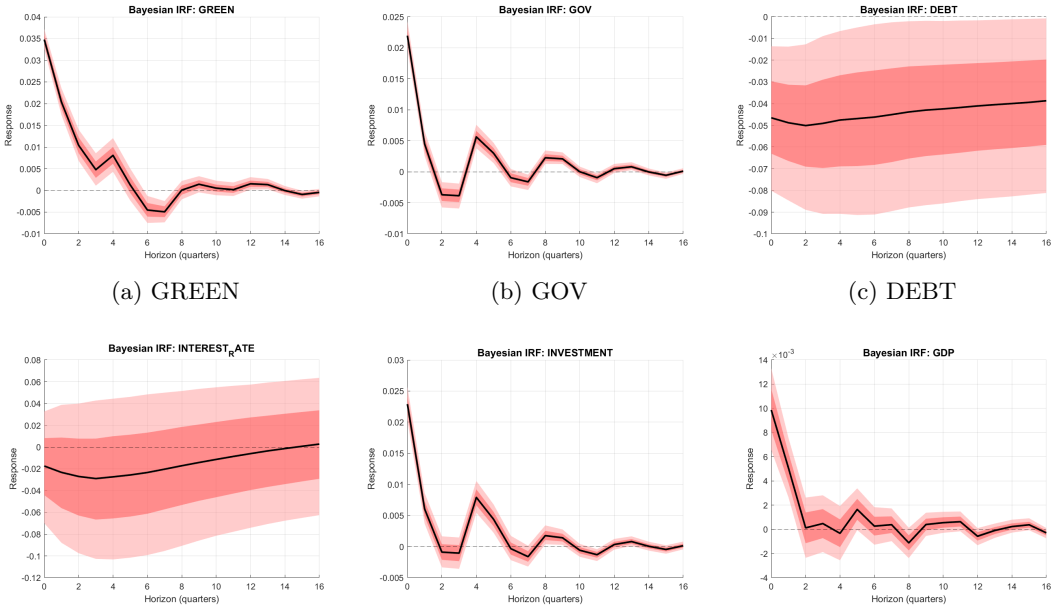
clear "crowding-in" effect, despite potential fiscal space limitations. This pattern contrasts with the shorter-lived response seen in Northern countries.

Public debt: The debt-to-GDP ratio exhibits a gradual downward trend, consistent with a cautious and potentially sustainable fiscal trajectory following the stimulus.

Long-term interest rates: The observed decline in the interest rate should not be interpreted as a direct monetary policy action. Rather, it reflects market expectations, a lower sovereign risk premium, or improved fiscal outlooks triggered by the green spending shock.

North–South asymmetries: Compared to Northern Europe, Southern European economies exhibit a more gradual and persistent reaction to green fiscal shocks. While responses in the North are quicker and short-lived, the South shows a delayed but more sustained and effective transmission, particularly in output and investment dynamics.

In summary, green spending shocks in Southern Europe produce more persistent and favorable effects on real economic activity, accompanied by an improving debt path and falling long-term interest rates — the latter likely reflecting market confidence rather than active monetary accommodation. We now turn to the results obtained from the Bayesian Panel VAR estimated for Eastern European countries, including Poland, Hungary, Czech Republic, Slovenia, Slovakia, and Romania. This section explores how structural shocks to green spending influence macroeconomic variables (GDP, investment, public debt, long-term interest rates) in Eastern Europe, and highlights potential asymmetries and divergences compared to the Northern and Southern blocs previously analyzed.



(a) GREEN (b) GOV (c) DEBT

(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 7: IRFs to Green Shock – East European Countries

The impulse responses (figure 6) for Eastern European countries (Poland, Hungary, Czech Republic, Slovenia, Slovakia, and Romania) display distinct dynamics compared to both Southern and Northern European countries. Following a green spending shock, we observe an immediate and sharp increase in green investment, which is however less persistent than in Southern Europe. This suggests a more short-term reaction capacity, possibly reflecting more flexible investment frameworks or project-based funding mechanisms in these economies.

The response of total government spending is positive and relatively volatile in the short run,

but quickly fades and stabilizes around zero, indicating limited fiscal propagation beyond the initial quarters. This may be due to stricter budgetary constraints or faster fiscal consolidation dynamics in these countries.

Debt levels decrease moderately and persistently, albeit with wide uncertainty bands, similarly to what is observed in Southern Europe. This may reflect a relatively cautious fiscal stance in response to green investments, or more conservative borrowing behavior.

The interest rate responds negatively to the shock, suggesting an accommodative or neutral monetary policy stance, which aligns with the observed mild inflationary pressures in the region. However, compared to Southern Europe, the reaction is milder and reverts faster to zero.

Investment and GDP both react positively, with GDP effects being more short-lived and less significant than in the South, while investment dynamics are slightly more pronounced initially but do not persist. This indicates that the short-term macroeconomic transmission of green shocks is somewhat effective in boosting demand, yet less persistent than in Southern Europe.

Compared to Northern Europe, the responses in Eastern Europe are closer in shape but of smaller magnitude. Northern countries tend to display more persistent effects on GDP and investment, along with stronger fiscal crowd-in effects. In contrast, Eastern European countries show more contained reactions, possibly due to structural differences in public administration efficiency, EU fund absorption capacity, or macroeconomic volatility.

Overall, the Eastern European region reacts positively yet cautiously to green spending shocks, with less persistence and lower magnitude than in Southern Europe, but still broadly aligned with expansionary dynamics observed in the rest of the EU. To conclude this section, it is important to highlight that the impulse responses obtained under a structural identification scheme Blanchard and Perotti (2002) display an immediate reaction of the endogenous variables to the identified fiscal shock. This is consistent with the assumption that fiscal policy shocks—such as government spending or green public investment—are contemporaneously exogenous to macroeconomic conditions due to institutional implementation lags.

As emphasized by Ramey and Zubairy (2018), such timing assumptions lead to a more immediate dynamic response compared to alternative narrative identification approaches, which typically imply a delayed reaction to fiscal announcements due to their anticipatory nature.

Furthermore, the responses of debt and interest rates align well with findings in the empirical literature. In particular, Auerbach and Gorodnichenko (2017) document that, under certain identification schemes, government spending shocks tend to lead to persistent reductions in public debt and downward pressure on interest rates—especially when fiscal expansions are perceived as credible and non-permanent. Our results confirm these dynamics across different regional panels, further supporting the robustness of our identification and estimation strategy.

4.1 Linear Fiscal Multipliers

As emphasized by Ramey and Zubairy (2018), estimating fiscal multipliers in a dynamic setting poses numerous methodological challenges and is inherently fraught with uncertainty. The seminal contribution by Blanchard and Perotti (2002) defines the multiplier as the ratio between the peak response of output and the size of the initial government spending shock. This "peak multiplier" approach has been widely adopted in the literature, including in influential studies by Auerbach and Gorodnichenko (2012, 2013).

An alternative methodology has been proposed by Mountford and Uhlig (2009),Fisher and Peters (2010), and Uhlig (2010), who argue that fiscal multipliers should instead be calculated as the ratio of the cumulative response of output to the cumulative response of government spending over a given horizon. These so-called integral multipliers offer a more policy-relevant perspective, as they capture the total increase in GDP relative to the total fiscal stimulus within a defined time window.

The Blanchard-Perotti method, in contrast, tends to yield higher multiplier estimates compared to the cumulative approach. This divergence likely reflects differences in the assumed timing of economic reactions and the identification strategies used to isolate exogenous fiscal shocks.

We compute cumulative fiscal multipliers following Ramey and Zubairy (2018) . For each regime $s \in \{\text{low}, \text{high}\}$, we use log-level impulse response functions (IRFs) of output and government spending. Output IRFs are cumulative log changes; spending IRFs are scaled by the lagged G/Y ratio to express changes in output units. Formally:

$$\text{IRF}_Y^s(h) = \sum_{j=0}^{h} \log Y_{t+j} - \log Y_{t+j-1}, \quad \text{IRF}_G^s(h) = \left(\sum_{j=0}^{h} \log G_{t+j} - \log G_{t+j-1} \right) \cdot \frac{G_{t-1}}{Y_{t-1}}.$$

The multiplier is then:

$$M^s(h) = \frac{\text{IRF}_Y^s(h)}{\text{IRF}_G^s(h)}.$$

Multipliers are computed for each posterior draw d, yielding a distribution $M^{s,(d)}(h)$. From this we extract:

$$\text{Median: } \text{median}_d(M^{s,(d)}(h)), \quad 68\% \text{ CI: } [P_{16}, P_{84}], \quad 95\% \text{ CI: } [P_{2.5}, P_{97.5}].$$

This ensures multipliers are expressed as the cumulative change in output per unit change in spending-to-GDP.

Table 1: Cumulative Fiscal Multipliers by Geographic Area

Horizon	**East EU**	**South EU**	**North EU**
GDP			
H = 0	0.28	0.29	0.18
1° year	0.19	0.13	0.13
2° year	0.23	0.20	0.1182
3° year	0.23	0.22	0.1149
Investment			
H = 0	0.65	0.41	0.19
1° year	0.44	0.35	0.17
2° year	0.55	0.55	0.05
3° year	0.52	0.60	0.07

Table 1 reports the cumulative fiscal multipliers for GDP and private investment across three regional aggregates — Eastern, Southern, and Northern Europe — over a horizon from impact (H = 0) to the third year.

A first key finding is that multipliers on private investment are systematically higher than those on GDP across all regions and time horizons, indicating that green public spending tends to crowd in private investment more effectively than it boosts output directly. This effect is particularly pronounced in Eastern Europe, where the investment multiplier reaches 0.65 on impact and remains above 0.50 after three years. Southern Europe also displays a sustained and increasing response, with the investment multiplier rising to 0.60 by the third year. By contrast, Northern Europe shows much more muted and short-lived effects, with investment multipliers approaching zero by the second year.

Regarding GDP multipliers, values remain below one across all regions, but Eastern and Southern Europe exhibit more persistent responses, while in Northern Europe, the effects diminish rapidly, falling below 0.12 by the second year.

These heterogeneous patterns may reflect structural differences in the transmission mechanisms of public spending, the absorptive capacity of private investment, and the cyclical position of each region. Additionally, it is plausible that economic agents perceive green spending differently across regions. In Northern European countries, where the baseline level of green spending is already high, additional investment may be perceived as less novel or urgent, resulting in weaker marginal responses. Conversely, in Southern and Eastern Europe, where fiscal space and environmental investment are more constrained, green spending may signal a credible long-term commitment to climate policy, thereby generating stronger and more persistent economic effects.

Overall, these results suggest that the effectiveness of green fiscal expansions is highly context-dependent, shaped by regional structural conditions, expectations, and institutional credibility.

5 Model: Panel Smooth Transition BVAR

In this section, we extend the analysis by implementing a Panel Smooth Transition Bayesian VAR (P-STBVAR), which allows us to capture potential nonlinearities in the response of macroeconomic variables to green spending shocks. The model incorporates a regime-switching structure, where parameters evolve smoothly depending on the level of public debt, through a logistic transition function. We estimate two versions of the model:

- one restricted to Euro Area countries included in our sample;
- the other covering all 18 EU member states considered in the analysis.

This dual specification enables us to compare the macroeconomic responses to green spending shocks between Euro Area and non-Euro Area countries, shedding light on the role of institutional and monetary frameworks in shaping fiscal effectiveness.

Moreover, the nonlinear structure allows us to explicitly distinguish the dynamic responses under low- and high-debt regimes. In doing so, we assess whether and how the responses of key economic variables—such as GDP, investment, interest rates, and public debt—differ depending on the initial fiscal position of the country. This is particularly relevant, as recent literature suggests (Huidrom et al., 2020; Ilzetzki et al., 2013; Bentour, 2022) that the effectiveness of fiscal interventions can be significantly influenced by the perceived sustainability of public finances.

To account for potential nonlinearities in the transmission of green fiscal shocks, we estimate a Panel Smooth Transition Bayesian VAR (ST-BVAR). This model allows impulse responses to vary smoothly across regimes defined by the level of public debt through a logistic transition function. The model specification is as follows:

$$\mathbf{y}_{i,t} = \sum_{l=1}^{p} A_l \mathbf{y}_{i,t-l} + \mathbf{Z}_{i,t}\Psi + \varepsilon_{i,t} \tag{7}$$

$$\varepsilon_{i,t} \sim \mathcal{N}(0, \Sigma) \tag{8}$$

where $Y_{i,t}$ is a $Kx1$ vector of endogenous variables for country i at time t, A_l are the KxK lag coefficient matrices, $Z_{i,t}$ includes fixed effects (country and time), and $\epsilon_{i,t}$ is a Gaussian error term.

The smooth transition mechanism is captured via a logistic function:

$$G(debt_{i,t}) = \frac{1}{1 + \exp(-\gamma(debt_{i,t} - c))} \tag{9}$$

Where $Debit_{i,t}$,denotes the public debt ratio, c is the threshold level (set to the cross-sectional median), and $\gamma > 0$ governs the speed of transition between regimes.

The prior on the coefficients follows a Minnesota-type structure (Primiceri et al., 2015) , with hyperparameters:

- λ for overall tightness,
- θ for cross-variable shrinkage,
- δ for lag decay.

Posterior inference is carried out via Gibbs sampling, separately for each regime (low and high debt), by weighting observations with $1 - G(debit_{i,t})$ and $G(debit_{i,t}$ respectively. We compute impulse response functions (IRFs) using the companion form and a Cholesky decomposition of the average covariance matrix across regimes. Finally, we calculate cumulative multipliers following the methodology of Ramey and Zubairy (2018), comparing the relative effects of green spending shocks in the two regimes.

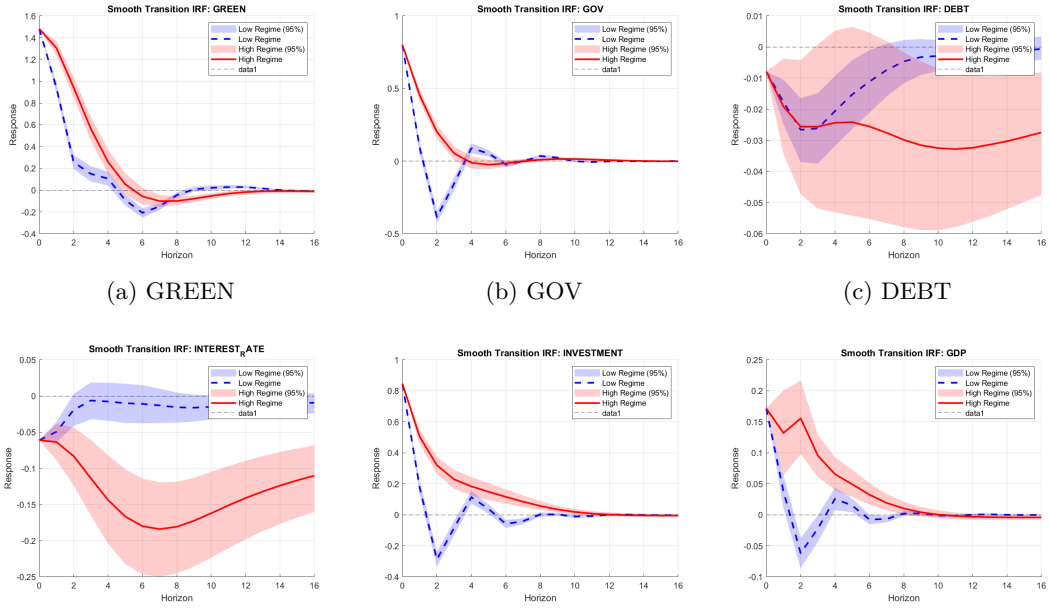
To assess heterogeneity, we estimate the model separately for:

- Euro Area countries,
- all 18 EU member states in the sample.

This allows us to explore the fiscal transmission mechanism across monetary regimes.

We begin by analyzing the nonlinear dynamic effects of green public spending in the subset of Euro Area countries using the Panel Smooth Transition Bayesian VAR. This framework allows us to capture differences in the impulse responses under low and high public debt regimes.

The Euro Area is a particularly relevant group for this analysis, given the common monetary policy framework and fiscal constraints imposed by the Stability and Growth Pact. These institutional features may influence both the market perception of fiscal sustainability and the macroeconomic effectiveness of green fiscal expansions.



(a) GREEN (b) GOV (c) DEBT

(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 8: IRFs to Green Shock – EUROZONE

The impulse response analysis from the Bayesian Smooth Transition VAR highlights a clear regime-dependent effect of green spending shocks. In particular, we find that the economic impact of green fiscal expansions is significantly amplified during periods of high public debt. Output and private investment respond more strongly in the high-debt regime, suggesting that green public spending may be more effective when macroeconomic slack or fiscal stress is elevated.

One of the most salient results concerns the behavior of long-term interest rates, which decline notably following a green spending shock, especially in high-debt regimes. This pattern is consistent with the idea that financial markets may revise downward the risk premium in response to credible and productive green fiscal expansions. Such investments are perceived as growth-enhancing, capable of stimulating private activity, strengthening long-run output, hedging future climate-related risks, and contributing to lower and more stable energy prices.

Moreover, the muted response of interest rates alongside a declining public debt trajectory supports the view that green spending is not perceived as fiscally destabilizing, unlike undifferentiated public spending. These findings echo results from the literature (Auerbach and Gorodnichenko, 2017), where interest rates and debt tend to decline in recessions following productive government spending shocks.

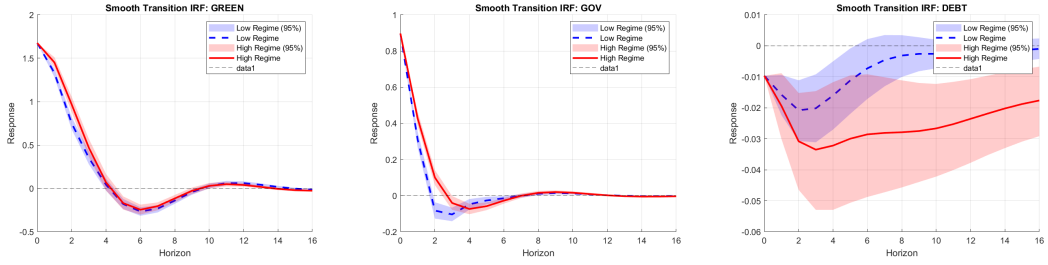
In sum, our evidence suggests that green fiscal expansions can be particularly potent and well-received in fiscally constrained environments, potentially due to their long-term economic and environmental benefits and their ability to foster market confidence.

To broaden the scope of our analysis, we extend the estimation of the Smooth Transition Bayesian VAR to the entire panel of 18 European Union countries in our dataset. This allows us to investigate whether the dynamics observed in the Euro Area also hold in a broader institutional context that includes both euro and non-euro member states.

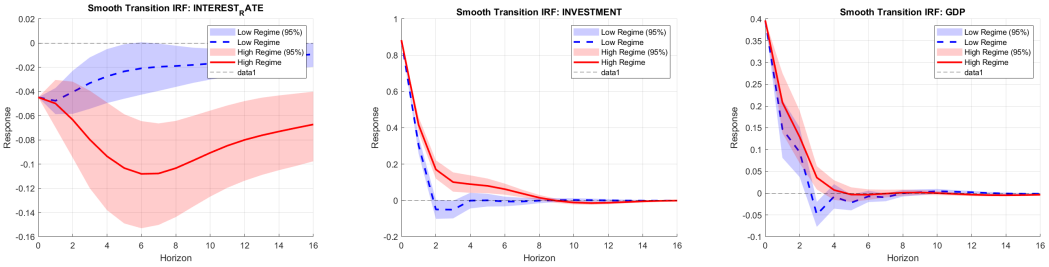
The model retains the same structural specification and estimation strategy used in the euro area PST-BVAR. However, by including a more heterogeneous set of countries—with varying fiscal capacities, institutional frameworks, and degrees of green investment intensity—we can assess the robustness and external validity of our baseline findings.

By exploiting the smooth transition framework, we continue to differentiate between low-debt and high-debt regimes, examining how macroeconomic responses to green public spending shocks vary across these fiscal conditions. This extension is particularly relevant, as it captures a wider spectrum of fiscal environments and policy constraints across the EU.

The goal is to understand whether green fiscal expansions are similarly effective across the entire European Union, or whether their effectiveness depends more strongly on fiscal space and country characteristics outside the euro area framework.



(a) GREEN (b) GOV (c) DEBT



(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 9: IRFs to Green Shock – EUROPEAN UNION

The impulse responses to the green spending shock reveal a substantial overlap between the two regimes (high and low public debt), particularly in the short term. This suggests that, at the aggregate EU level, the initial reaction to the shock is relatively uniform. However, two key dynamics stand out: The first Interest Rates: As observed in the Eurozone sample, long-term interest rates decrease significantly under the high-debt regime, while they remain more stable under the low-debt regime. This behavior likely reflects more favorable market expectations, viewing green spending as a stabilizing force in the long run (e.g., mitigating climate-related risks and reducing energy cost volatility). The second Public Debt: The response of public debt shows a more pronounced decline in high-debt conditions, consistent with the notion that well-targeted green spending can stimulate potential output and improve fiscal sustainability over the medium term. Other variables (GDP, investment, and public spending) show relatively similar responses across regimes, though slightly more persistent effects under the high-debt regime, suggesting that green fiscal expansions may be more effective in contexts of fiscal fragility.

5.1 Fiscal Multipliers

In order to capture the state-dependency of fiscal effects, we extend our analysis by estimating non-linear fiscal multipliers using a Bayesian Smooth Transition Panel VAR (PSTBVAR). This methodology allows the multiplier to vary smoothly across regimes—typically distinguished by a threshold variable such as the debt-to-GDP ratio—rather than assuming a single, static value, as in linear VARs (Auerbach and Gorodnichenko, 2012; Fotiou, 2022; Canzoneri et al., 2016)

Table 2: Fiscal Multipliers – Eurozone

Horizon	**GDP High**	**GDP Low**	**Inv. High**	**Inv. Low**
H=0	0.1162	0.1100	0.57	0.57
Year 1	0.1174	0.0300	0.43	0.26
Year 2	0.1400	0.0410	0.53	0.28
Year 3	0.1500	0.0404	0.56	0.26

Table 3: Fiscal Multipliers – European Union

Horizon	GDP High	GDP Low	Inv. High	Inv. Low
H=0	0.23	0.23	0.53	0.53
Year 1	0.14	0.14	0.32	0.25
Year 2	0.17	0.1655	0.42	0.29
Year 3	0.16	0.1630	0.40	0.28

The nonlinear fiscal multipliers estimated using the Smooth Transition Bayesian VAR model reveal significant differences across regimes and regions. In the Euro Area, GDP multipliers are consistently higher in the high debt regime compared to the low debt regime. For instance, by the third year, the cumulative multiplier reaches 0.15 in the high debt regime, compared to just 0.04 in the low debt regime. This suggests that green fiscal expansions are more effective when public debt is elevated.

Investment multipliers exhibit even stronger regime dependence: they remain high and stable (around 0.56–0.57) under high debt conditions, while they are much lower and flatter in the low debt regime (0.26–0.28). This indicates that private investment responds more positively to green spending when fiscal conditions are tight, possibly due to stronger signaling effects or expectations of long-term benefits.

When extending the analysis to the entire European Union (including non-euro countries), the divergence between regimes becomes slightly smaller for GDP, with third-year multipliers of 0.16 (high debt) and 0.163 (low debt). This suggests a more homogeneous response across regimes outside the euro area, perhaps due to different monetary policy regimes or lower financial integration. However, the response of private investment remains substantially higher in the high debt regime (0.40 vs. 0.29), confirming that green fiscal spending has a stronger crowd-in effect under fiscal stress.

Overall, the results highlight that green fiscal multipliers are generally below one and highly state-dependent, with significantly larger effects during periods of high debt—especially for private investment. These findings align with theoretical expectations on the effectiveness of green spending during economic downturns and provide relevant policy insights for the design of climate-related countercyclical fiscal strategies.

6 Alternative Fiscal Shocks: Green vs. Non-Green Spending

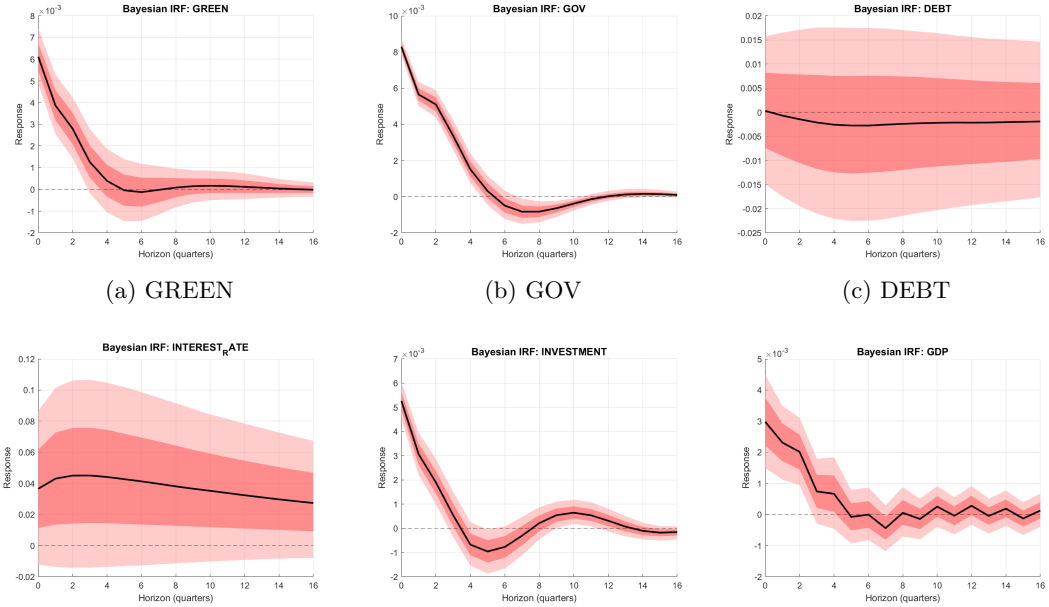
In this section, we conduct a shock comparison exercise to assess whether the previously observed effects—particularly on public debt and interest rate dynamics—are specific to the green component of public spending. To this end, we re-estimate the model by identifying a shock to total public spending net of green expenditures. This comparison allows us to evaluate the extent to which the favorable effects attributed to green spending are distinguishable from those triggered by more generic fiscal expansions.

6.1 Linear Model: Bayesian VAR

In this subsection, we estimate a linear VAR model for Northern European countries using a shock to total public spending net of the green component. The shock is identified through a Cholesky decomposition, ordering total net spending first as the most exogenous variable.

The aim is to assess the response of key macroeconomic variables—public debt, 10-year interest rates, private investment, and GDP—to a conventional fiscal shock, that is, a shock not explicitly targeted toward the green transition. This robustness exercise allows us to compare the effects of generic public spending with those of green spending analyzed in previous sections and to

explore whether market reactions and agent expectations differ depending on the nature of the fiscal stimulus.



(a) GREEN (b) GOV (c) DEBT

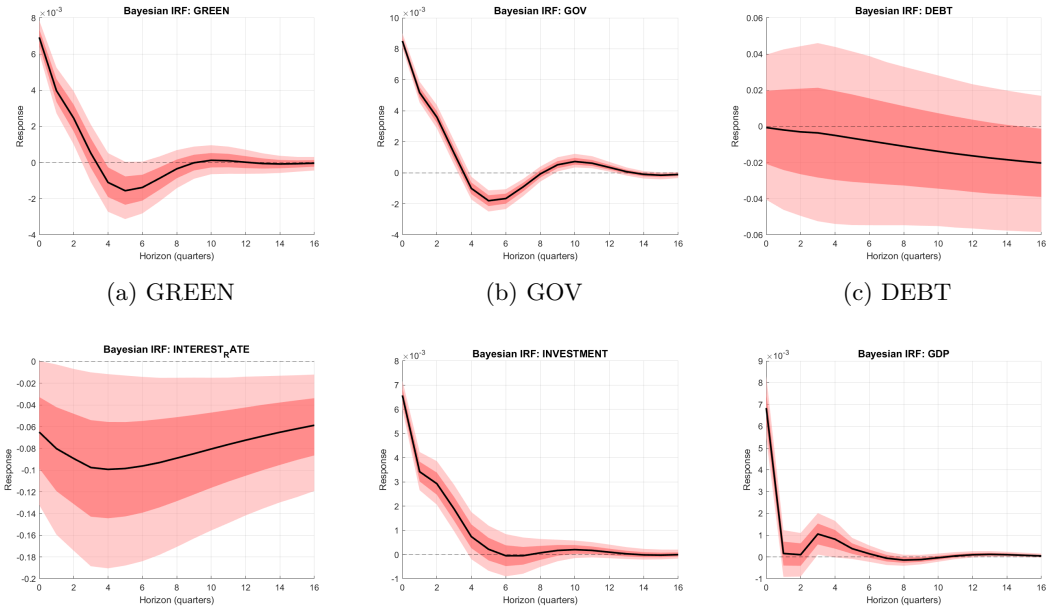
(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 10: IRFs Total Government Spending -North European Countries

We now compare the impulse responses to a total public spending shock net of green expenditures with those from a green spending shock. Although the dynamic pattern of macroeconomic variables appears qualitatively similar across the two shocks, the magnitude of the responses is notably stronger in the case of the total (non-green) spending shock.

For instance, GDP reacts positively on impact but returns to zero after approximately four quarters, whereas in the green spending case, the output response dissipates within two quarters. This indicates a faster reversion to baseline after a green shock. Investment shows a nearly identical response path across the two shocks, though the magnitude is larger in the total spending shock—as can be seen by comparing the vertical axes of the respective IRFs.

A key point of divergence lies in the behavior of interest rates. While green spending shocks lead to a decrease in long-term interest rates—suggesting improved expectations regarding fiscal sustainability—non-green spending shocks produce a persistent increase in interest rates. This distinction may indicate that financial markets perceive green public spending as more credible and beneficial for long-term growth and climate resilience, thus reducing risk premiums. Below we report the results of the total government shock in Southern Europe.

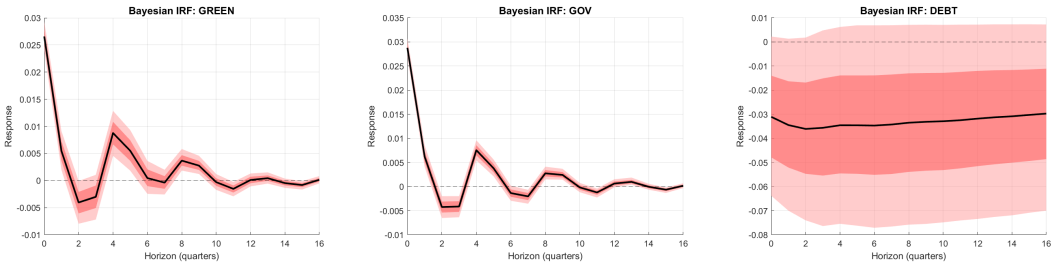


(a) GREEN (b) GOV (c) DEBT

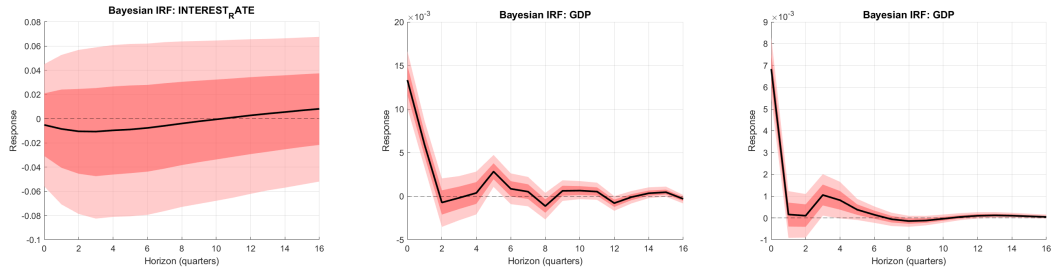
(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 11: IRFs Total Government Spending -South European Countries

Compared to the green spending shock, ordinary public spending shows initially larger effects, but they fade more quickly. Although the short-term multipliers exceed one, economic agents appear to perceive this type of spending as less productive or of lower quality. Public debt does not decline—as it does in response to green shocks—suggesting that markets do not associate ordinary spending with improved fiscal sustainability, despite its initial effect on GDP. Interest rates fall slightly, but less than in the green spending case, indicating lower investor confidence in the fiscal expansion. In summary, green spending appears more effective in stimulating the economy in a fiscally sustainable way, as markets perceive it more favorably than undifferentiated public expenditures. Below, we present the results for the Eastern European panel in response to a total public spending shock net of green spending.



(a) GREEN (b) GOV (c) DEBT



(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 12: IRFs Total Government Spending -East European Countries

The shock to total government spending, net of the green component, generates dynamics that are very similar to those triggered by a green spending shock, but with a significantly larger magnitude. This pattern is consistently observed across the Eastern European countries, suggesting a qualitatively similar but quantitatively stronger macroeconomic response in the case of general fiscal stimuli.

6.1.1 Linear fiscal multiplier total government spending

We assess the impact of public spending through impulse response functions (IRFs), expressing the effects in terms of fiscal multipliers.

Table 4: Cumulative Fiscal Multipliers by Geographic Area

Horizon	**East EU**	**South EU**	**North EU**
GDP			
H = 0	0.46	0.80	0.61
1° year	0.54	0.51	0.40
2° year	0.5723	0.70	0.36
3° year	0.5744	0.62	0.47
Investment			
H = 0	1.03	0.77	0.3523
1° year	1.38	0.88	0.3544
2° year	1.39	1.20	0.36
3° year	1.35	1.06	0.40

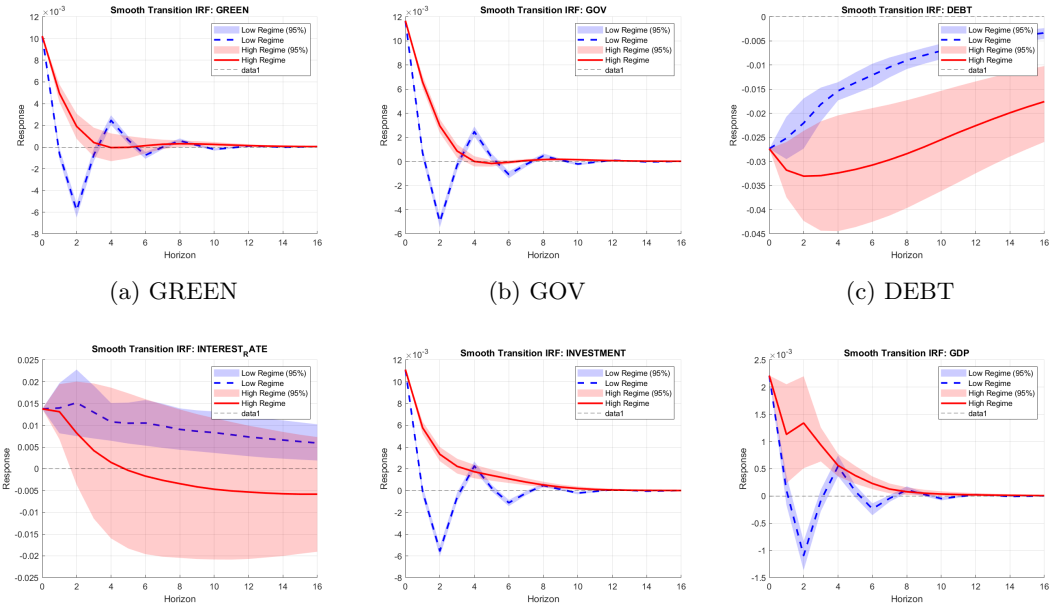
Table 4 shows that cumulative fiscal multipliers for total public spending vary significantly across European regions. For GDP, Southern European countries display the highest multipliers in the medium term (up to 0.82 in the third year), followed by Eastern Europe, while Northern Europe shows lower values, with an initial peak of 0.61 that gradually declines. In all regions, GDP multipliers remain below one, suggesting only a partial expansionary effect on overall output.

As for investment, multipliers exceed one in all regions, though with varying intensity: Eastern Europe records the highest values (up to 1.35 in the third year), followed by Southern Europe, while Northern Europe shows more modest and stable values. This indicates a clear crowding-in effect, whereby public spending also stimulates private investment, at least in the medium term.

Overall, the results suggest that the effectiveness of total public spending (excluding green spending) is relatively higher in Southern and Eastern Europe. In Northern Europe, the smaller impact may reflect diminishing marginal returns, given the already high level of public expenditure relative to GDP and the lower capacity of additional spending to further stimulate the economy in a context close to full capacity.

6.2 Model: Smooth Transition BVAR

We estimate a nonlinear Smooth Transition Panel Bayesian VAR (ST-P-BVAR) model to examine the effects of a total government spending shock, net of green expenditures, across Eurozone countries. The model allows for regime-dependent dynamics by incorporating a smooth transition function based on the level of public debt. Specifically, we distinguish between high-debt and low-debt regimes, enabling us to assess whether the macroeconomic effects of fiscal shocks differ systematically depending on countries' fiscal space. By adopting a Bayesian approach within a panel framework, the model captures cross-country heterogeneity while maintaining statistical efficiency. This setup is particularly suited to investigate asymmetric responses to fiscal policy in the context of varying debt conditions across Euro Area economies.



(a) GREEN (b) GOV (c) DEBT

(d) INTEREST RATE (e) INVESTMENT (f) GDP

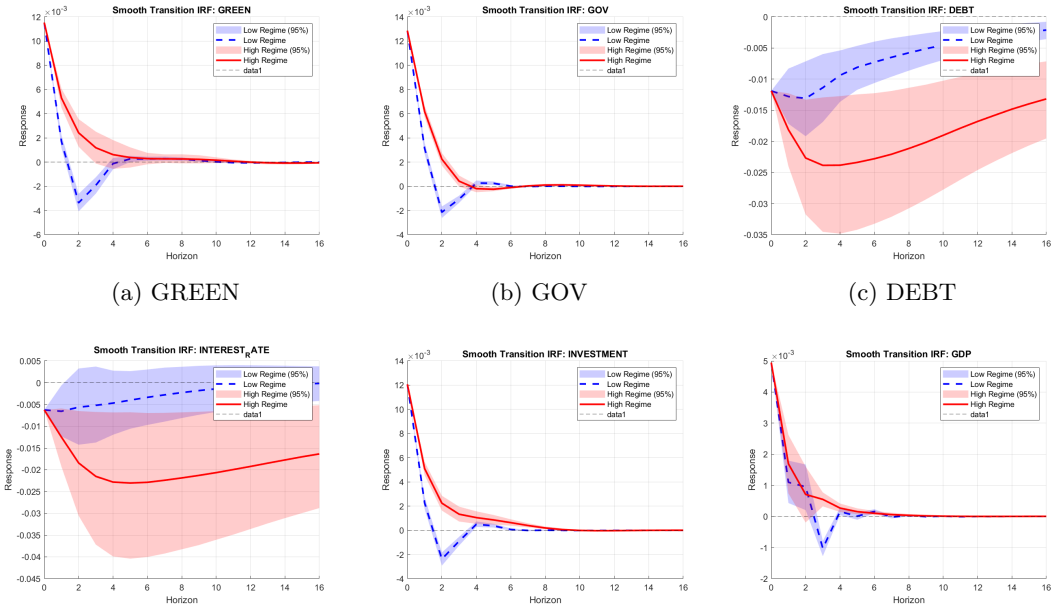
Figure 13: IRFs Total Government Spending -EUROZONE

The smooth transition panel Bayesian VAR estimates reveal that the dynamic responses to a total government spending shock—net of green expenditures—are broadly similar to those observed for green spending shocks in terms of GDP and investment responses. However, notable differences emerge in the interest rate and debt trajectories. Specifically, while green fiscal shocks lead to a decline in interest rates under high-debt regimes—possibly reflecting increased expectations of long-term productivity or targeted stimulus effects—total government spending shocks elicit a rise in interest rates across both regimes. This divergence suggests that financial markets and economic agents may perceive traditional fiscal expansions as less credible or more inflationary,

triggering a positive risk premium or expectations of future tightening.

Additionally, although public debt initially declines following both types of fiscal shocks—likely reflecting a short-run fiscal multiplier or revenue feedback—the path of debt differs in the medium term. In the case of total government spending shocks, debt gradually returns to its pre-shock level after a few quarters, contrasting with more persistent debt reductions observed under green spending scenarios. This pattern reinforces the interpretation that market perceptions of fiscal sustainability and long-run returns differ markedly between green and conventional government spending.

We extend our analysis to estimate the effects of a total government spending shock net of green public expenditures across a broader sample of 18 European countries, including both Eurozone and non-Eurozone members. This broader scope allows us to assess whether the dynamic responses to fiscal shocks differ when monetary policy autonomy and exchange rate regimes vary across countries. The spending shock is constructed by isolating the component of total government expenditure that is not attributable to green investment, following the same methodology applied in the Euro Area sub-sample. This approach enables a consistent comparison of fiscal transmission mechanisms and the potential crowding-in or crowding-out effects of non-green spending across heterogeneous institutional and macroeconomic environments.



(a) GREEN (b) GOV (c) DEBT

(d) INTEREST RATE (e) INVESTMENT (f) GDP

Figure 14: IRFs Total Government Spending - European Union

This section analyzes the macroeconomic effects of a public spending shock net of the green component, estimated using a Smooth Transition VAR (STVAR) model across 18 EU member states, including both eurozone and non-euro countries (Germany, France, Italy, Austria, Greece, Spain, Portugal, Belgium, Netherlands, Denmark, Sweden, Finland, Poland, Hungary, Czech Republic, Slovakia, Slovenia, Romania).

The impulse response functions (IRFs) show that:

- The dynamic responses are qualitatively similar to those triggered by green spending shocks, but the magnitude differs, with the total spending shock generating slightly larger effects on real variables (GDP and investment), especially in the high-debt regime.
- Interest rates, notably 10-year government bond yields, decline modestly in both regimes,

suggesting that the shock is not perceived as a signal of fiscal risk or monetary pressure—at least not in the broader EU sample. While the real-side effects (on GDP and investment) of total spending shocks are similar across country groups, the behavior of long-term interest rates differs significantly. In the euro area, yields rise in response to spending shocks, signaling heightened fiscal risk perception. In contrast, in the broader EU sample, yields decline, indicating more benign or even accommodative financial market expectations.

6.2.1 Fiscal multipliers on total government spending shock

In this section, we estimate fiscal multipliers for total public spending (net of green components) using the same approach applied to green spending shocks. Multipliers are computed from the impulse responses generated by two separate STVAR models:

one estimated on the 12 euro area countries, and

one on the full sample of 18 EU countries, including both euro and non-euro members.

Table 5: Fiscal Multipliers – Eurozone

Horizon	**GDP High**	**GDP Low**	**Inv. High**	**Inv. Low**
H=0	0.18	0.18	0.94	0.95
Year 1	0.28	0.1779	1.09	0.75
Year 2	0.3172	0.1788	1.27	0.72
Year 3	0.3159	0.1792	1.26	0.71

Table 6: Fiscal Multipliers – European Union

Horizon	**GDP High**	**GDP Low**	**Inv. High**	**Inv. Low**
H=0	0.37	0.37	0.93	0.93
Year 1	0.35	0.4628	1.01	0.89
Year 2	0.3950	0.4678	1.12	0.89
Year 3	0.3911	0.4680	1.10	0.8963

Tables 4 and 5 report fiscal multipliers for GDP and private investment in the Euro Area and the European Union, distinguishing between high-debt and low-debt regimes. The results highlight significant heterogeneity in fiscal policy effectiveness depending on debt conditions, but also some common patterns.

In the case of the Euro Area (Table 6), GDP multipliers are slightly higher under high debt (up to 0.31 by year three), consistent with the hypothesis of greater fiscal effectiveness during recessions, as emphasized by Auerbach and Gorodnichenko (2012). It is plausible that the high-debt regime empirically overlaps with adverse economic conditions, where fiscal policy has more pronounced effects. However, it is important to note that GDP multipliers remain below one in both regimes, suggesting a limited aggregate growth response to public spending. In contrast, investment multipliers are substantially larger under high debt (1.30 vs. 0.71), indicating a stronger private sector response—possibly driven by higher expectations of public support or more targeted fiscal interventions.This aspect may suggest the forward-looking nature of private investment, which responds more to the initial impulse and expectations than to the actual evolution of the cost of capital in the medium term.

In the broader European Union (Table 5), the pattern reverses for GDP: multipliers are higher under low debt (0.4680 vs. 0.3011), supporting the notion that greater fiscal space enhances the effectiveness of fiscal stimulus. Nevertheless, multipliers remain below one, reinforcing the view that fiscal expansions have a moderate impact on output overall. Investment multipliers are again somewhat higher under high debt (1.10 vs. 0.98), although the difference is less pronounced than in the Euro Area.

Finally, when compared to the previously analyzed green spending shocks, the multipliers from total public spending appear significantly larger. However, this mainly reflects the difference in shock intensity: green expenditures represent a very small share of GDP, and thus generate more limited aggregate effects. Despite this, green shocks exhibit more favorable macro-financial dynamics, particularly in the context of high debt. In the Euro Area panel, green fiscal shocks lead to a marked reduction in interest rates and public debt, especially under high-debt conditions. By contrast, total public spending increases interest rates and does not reduce debt levels. These findings suggest that—even with smaller multipliers—green investments may offer a more sustainable path to economic stimulus, combining demand support with improved fiscal sustainability in the medium term.

7 Conclusions

Based on the premises outlined — namely, how to reconcile green public investment with the renewed need for fiscal consolidation that emerged after the pandemic crisis — our results suggest that green fiscal stimulus does not put upward pressure on interest rates or public debt levels. This indicates that financial markets do not perceive green spending as equivalent to general public expenditure. Even though we observe a counterintuitive behavior of private investment in response to total public spending shocks—where interest rates increase both under high and low debt conditions—investment multipliers indicate a crowding-in effect. This suggests that the interest rate channel is not the main determinant of private investment responses, which instead appear to be driven more by expectation effects and by the nature of the stimulus. We also find support for the hypothesis, highlighted in the literature by Ramey and Zubairy (2018); Mountford and Uhlig (2009); Haroon and Konstantinos (2020) , that fiscal multipliers have declined over time. On the one hand, this may reflect a reduced responsiveness of economic agents to fiscal policy; on the other, it may be due to the open nature of many economies, which leads to demand leakage abroad.

However, as noted by Sadler et al. (2024), current levels of green spending — particularly in research and development — remain insufficient to meet climate mitigation goals. Higher levels of green investment in the future, if well targeted, could yield more substantial GDP and private investment multipliers, combining sustainability and macroeconomic effectiveness.

Appendix A – Data Sources and Variable Definitions

Table 7: Data Sources and Definitions of Key Variables

Variable	**Description**	**Source**
Green Public Spending	Environmental protection expenditure (e.g. waste management, wastewater, biodiversity, R&D)	Eurostat (EPEA, COFOG)
Total Government Spending	General government expenditure by function (COFOG classification)	Eurostat (COFOG)
Public Debt-to-GDP	Government consolidated gross debt as percentage of GDP	Eurostat
Long-Term Interest Rate	10-year government bond yields	FRED (OECD Long-Term Rates)
Nominal GDP	Gross domestic product at current prices	FRED (OECD Quarterly National Accounts)
GDP Deflator	Implicit price deflator for GDP	FRED
Population	Total population (national estimate)	Eurostat

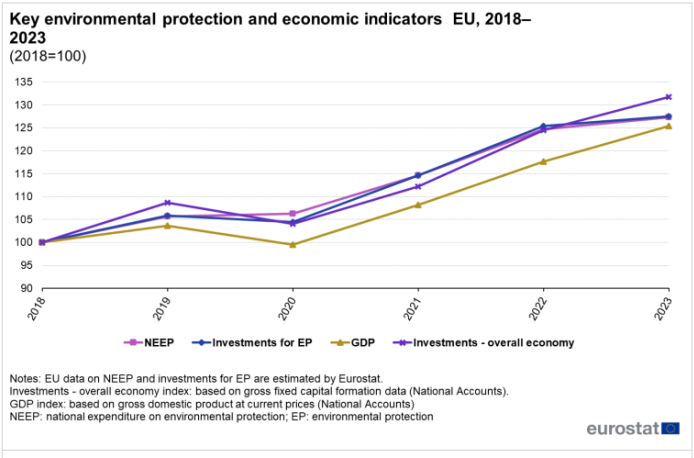


Figure 15: EU green expenditure indicators

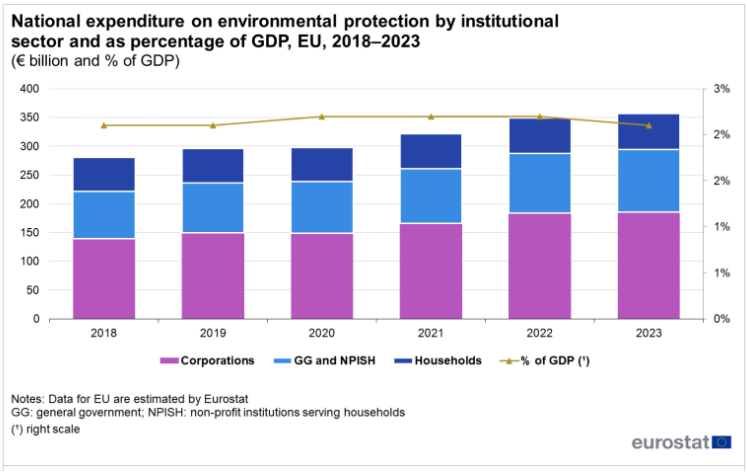


Figure 16: Share green expenditure for sector

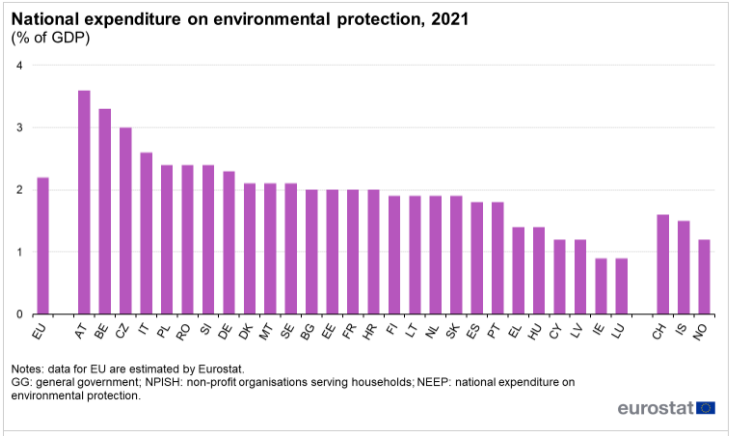
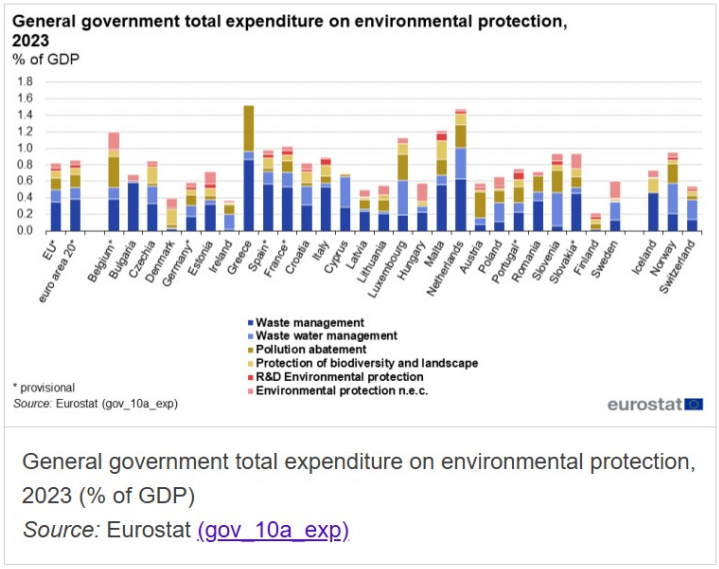


Figure 17: Green Public Spending

lavoratrice. La legge generale dell'accumulazione capitalistica corrisponde alla legge generale dell'accumulazione della miseria relativa. I dati sulla ripartizione del prodotto nei paesi capitalistici più avanzati tra la quota dei salari e la quota dei profitti sono una dimostrazione incontrovertibile dell'analisi marxista.

Figure 18: Green Investment Public



General government total expenditure on environmental protection, 2023 (% of GDP)

Source: Eurostat (gov_10a_exp)

Figure 19: Share Public Spending

References

Afonso, A. and Sousa, R. M. (2012). The macroeconomic effects of fiscal policy. *Applied Economics*, 44(34):4439–4454.

Agreement, P. (2015). Paris agreement. In *report of the conference of the parties to the United Nations framework convention on climate change (21st session, 2015: Paris). Retrived December*, volume 4, page 2. HeinOnline.

Auerbach, A. J. and Gorodnichenko, Y. (2012). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, 4(2):1–27.

Auerbach, A. J. and Gorodnichenko, Y. (2013). Output spillovers from fiscal policy. *American Economic Review*, 103(3):141–146.

Auerbach, A. J. and Gorodnichenko, Y. (2017). Fiscal stimulus and fiscal sustainability. Technical report, National Bureau of Economic Research.

Batini, N., Di Serio, M., Fragetta, M., Melina, G., and Waldron, A. (2022). Building back better: How big are green spending multipliers? *Ecological Economics*, 193:107305.

Bentour, E. M. (2022). The effects of public debt accumulation and business cycle on government spending multipliers. *Applied Economics*, 54(19):2231–2256.

Blanchard, O. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *the Quarterly Journal of economics*, 117(4):1329–1368.

Canzoneri, M., Collard, F., Dellas, H., and Diba, B. (2016). Fiscal multipliers in recessions. *The Economic Journal*, 126(590):75–108.

Ciaffi, G. (2025). Green fiscal multipliers and the energy transition. Working Paper.

Darvas, Z. M. and Wolff, G. B. (2021). A green fiscal pact: climate investment in times of budget consolidation. Technical report, Bruegel Policy Contribution.

Deleidi, M., Iafrate, F., and Levrero, E. S. (2020). Public investment fiscal multipliers: An empirical assessment for european countries. *Structural Change and Economic Dynamics*, 52:354–365.

Ficarra, M. (2024). Public spending, green growth, and corruption: a local fiscal multiplier analysis for italian provinces. Technical report, Graduate Institute of International and Development Studies Working Paper.

Fisher, J. D. and Peters, R. (2010). Using stock returns to identify government spending shocks. *The Economic Journal*, 120(544):414–436.

Fotiou, A. (2022). Non-linearities in fiscal policy: The role of debt. *European Economic Review*, 150:104212.

Haroon, M. and Konstantinos, T. (2020). Fiscal policy shocks and stock prices in the united states. *European Economic Review*, 129.

Huidrom, R., Kose, M. A., Lim, J. J., and Ohnsorge, F. L. (2020). Why do fiscal multipliers depend on fiscal positions? *Journal of Monetary Economics*, 114:109–125.

Ilzetzki, E., Mendoza, E. G., and Végh, C. A. (2013). How big (small?) are fiscal multipliers? *Journal of monetary economics*, 60(2):239–254.

Litterman, R. B. (1986). Forecasting with bayesian vector autoregressions—five years of experience. *Journal of Business & Economic Statistics*, 4(1):25–38.

Mountford, A. and Uhlig, H. (2009). What are the effects of fiscal policy shocks? *Journal of applied econometrics*, 24(6):960–992.

Primiceri, G. E., Giannone, D., and Lenza, M. (2015). Time-varying structural vector autoregressions and monetary policy. *Review of Economic Studies*, 82(4):1342–1380.

Ramey, V. A. and Zubairy, S. (2018). Government spending multipliers in good times and in bad: evidence from us historical data. *Journal of political economy*, 126(2):850–901.

Romer, C. D. and Romer, D. H. (2010). The macroeconomic effects of tax changes: estimates based on a new measure of fiscal shocks. *American economic review*, 100(3):763–801.

Saccone, D., Della Posta, P., Marelli, E., and Signorelli, M. (2022). Public investment multipliers by functions of government: An empirical analysis for european countries. *Structural Change and Economic Dynamics*, 60:531–545.

Sadler, A., Ranger, N., Fankhauser, S., Marotta, F., and O'Callaghan, B. (2024). The impact of covid-19 fiscal spending on climate change adaptation and resilience. *Nature Sustainability*, 7(3):270–281.

Uhlig, H. (2010). Some fiscal calculus. *American Economic Review*, 100(2):30–34.