Measuring Green Fiscal Multipliers: Heterogeneity in European Countries

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Abstract

This paper evaluates the macroeconomic impact of green public spending by quantifying the responses of GDP, private investment, employment, and labour productivity across 30 European countries from 1995 to 2020. Using linear and non-linear Local Projection methods, our findings indicate that green fiscal policies can positively and persistently affect GDP and employment levels, crowding-in private investment and generating a positive impact on productivity dynamics. When distinguishing between low- and high-income countries, we observe that the multipliers on GDP and employment are higher for the latter group, although no significant gains in productivity are found. However, productivity gains, albeit small in magnitude, appear to be concentrated in low-income countries. Moreover, our results show that the impact of green investments on GDP and private investment is higher in countries with high levels of green public consumption expenditure over total green public expenditure. These findings underline the importance of tailored fiscal policies to maximize the benefits of green public expenditure across different economic contexts.

Keywords: Green Public Spending, Fiscal Multipliers, Green Investment, Green Consumption, European Divide, Ecological Economics.

JEL Classification Codes: E62, Q54, Q58

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Introduction

Climate change and biodiversity collapse are the most urgent and complex challenges facing humanity today. Their far-reaching consequences affect not only the environment, but also economic stability, social cohesion, and geopolitical dynamics. Recent crises, such as the COVID-19 pandemic and the Russian-Ukrainian war, have exacerbated these challenges, diverting resources and attention while underscoring the fragility of global systems (Díaz et al., 2019; IPCC, 2021, 2022). These intertwined crises make the need for decisive action on climate change even more pressing, as failure to act risks compounding existing vulnerabilities and undermining long-term prosperity.

The economic implications of climate change are profound and require substantial investment to facilitate the transition to a sustainable, low-carbon economy. To achieve the goals set out in the Agreement, it is estimated that global infrastructure investment will need to range from \$3.1 trillion to \$5.8 trillion each year through 2050 (IEA, 2021). In addition to climate issues, researchers emphasize that climate change represents just the surface of much larger, interconnected environmental challenges (Bradshaw et al., 2021). This stark financing gap highlights the critical need for increased and more effective public investment to address the magnitude of the challenge.

Moreover, aligning global infrastructure with net-zero emissions targets will require yearly additional public investment estimated to range between 0.5% and 4.5% of GDP, with a consensus clustering around 2% of GDP (IMF[1], 2021). This scale of investment underscores the need for coordinated efforts between governments, international organizations, and the private sector. Yet, the burden cannot be shouldered by private capital alone; the public sector must play a pivotal role in catalyzing and de-risking the investments needed for a sustainable transition.

Europe, as a front-runner in climate ambition, exemplifies the scale of the challenge. To bridge the investment gap necessary for decarbonization and innovation, the European Union will need an estimated €750-800 billion annually between 2025 and 2030—equivalent to approximately 5% of the EU's GDP. This figure underscores the enormity of the task and the essential role of public sector intervention. The private sector, despite its critical contribution, is unlikely to finance the lion's share of these investments without substantial public support to mitigate risks and create enabling conditions (Draghi, 2024).

In response to these pressing challenges, the European Union has launched the Sustainable Europe Investment Plan, a bold initiative aimed at mobilizing €1 trillion in green investments across the EU by leveraging public resources to attract private capital (European Parliament, 2020). This ambitious plan represents a pivotal step in addressing the dual imperatives of decarbonization and sustainable growth. By channeling resources into green technologies, infrastructure, and innovation, the EU seeks to position itself as a global leader in the energy transition, while ensuring economic resilience and inclusivity.

The success of such initiatives will depend not only on the scale of investment, but also on the strategic allocation of resources to maximize their impact. This underscores the importance of understanding the macroeconomic effects of green public spending, including its capacity to stimulate economic growth, employment, and productivity. Through careful analysis and evidence-based policy design, the transformative potential of green fiscal policies can be fully realized, setting the foundation for a sustainable and prosperous future.

Against the backdrop of the EU decarbonisation agenda, our question is precise: what are the macroeconomic effects of green public expenditure in Europe? Policymakers need component-level evidence on how such spending — in particular public investment versus

[1] https://www.imf.org/en/Blogs/Articles/2021/07/22/blog-reaching-net-zero-emissions

public consumption — affects GDP, employment, private investment, and productivity.

Despite broad policy interest in green public spending, evidence on how its effects unfold across European countries remains limited. Few studies quantify the size of green fiscal multipliers and fewer still distinguish systematically between high- and low-income groups or between green investment and green consumption. The links to key macro variables—GDP, employment, private investment, and labour productivity—are often left implicit. We aim to bridge these gaps by providing a cross-country assessment for 30 European economies over 1995–2020 using local projections that separate green investment from green consumption and compare responses across income groups. Our estimates offer component-level benchmarks for the effects of green expenditure on output, jobs, private capital formation, and productivity. The analysis is reduced-form and intentionally parsimonious: we do not model explicit cross-country spillovers and allow limited heterogeneity beyond income-group splits. Within these limits, we document how income level and the composition of environmental outlays shape the effectiveness of green fiscal policy.

The remainder of the paper is organized as follows. Section 1 reviews the relevant literature, focusing on fiscal multipliers and the emerging scholarship on green public spending. Section 2 details the data construction, discusses the variables used in the analysis and outlines the econometric methodology, with special emphasis on the identification strategy for green fiscal shocks. Section 3 presents and interprets the empirical results, shedding light on differences between high- and low-income contexts as well as between consumption- and investment-driven green expenditures. Finally, the last section concludes with a discussion of policy implications and avenues for future research.

1 Literature Review

The examination of fiscal multipliers, as synthesized by Deleidi et al. (2023), provides critical insights into the effects of government expenditure on economic output, revealing a complex interplay of methodological approaches and empirical findings. The literature predominantly employs two methodological frameworks: model-based analyses utilizing Dynamic Stochastic General Equilibrium (DSGE) models and econometric techniques grounded in Structural Vector Autoregression (SVAR) models and Local Projections (LP).

Model-based approaches, particularly those leveraging Real Business Cycle (RBC) and New Keynesian (NK) DSGE models, evaluate the impact of discretionary fiscal policies by focusing on neoclassical wealth and substitution effects. These models suggest that fiscal multipliers can exhibit considerable variation contingent upon assumptions regarding household preferences, monetary policy responses, and the presence of a zero lower bound for nominal interest rates. Notably, NK-DSGE models, which incorporate rigidities such as monopolistic competition and price stickiness, generally yield larger fiscal multipliers compared to RBC models (Edelberg et al., 1999; Galí et al., 2007; Christiano et al., 2011).

Econometric techniques, particularly SVAR models, are extensively utilized to isolate exogenous fiscal policy shocks through various identification strategies, including recursive approaches, sign restrictions, and the Narrative Approach (NA). Recent studies have also adopted the LP approach, which offers advantages such as robustness to misspecifications and flexibility in accommodating nonlinear specifications (Jordà, 2005; Auerbach and Gorodnichenko, 2017; Ramey and Zubairy, 2018).

The estimated fiscal multipliers exhibit variability across studies, with an average value of approximately 1. Recursive and Blanchard-Perotti identification strategies tend to produce larger multipliers, whereas sign restriction strategies yield lower values. For instance, multipliers range from negative values to positives values with peak effect as high as 5.46, reflecting the diverse methodologies and economic contexts studied (Blanchard and Perotti, 2002; Perotti, 2004; Mountford and Uhlig, 2009).

While much of the literature focuses on total public expenditure, some studies differentiate between government investment and consumption. Findings are mixed, with some research suggesting that government investment is more effective in stimulating GDP, due to the existence of long-run supply-side effects on the public and private capital stock (Auerbach and Gorodnichenko, 2012; Burriel et al., 2010), while others show that investment is not more effective than consumption in stimulating GDP since private investment is crowded out by government investment (Perotti, 2004; Pappa, 2009; Ellahie and Ricco, 2017). Beyond single-study evidence, a meta-regression of 104 studies / 1,069 estimates(Gechert, 2015) finds that public spending multipliers are significantly positive and on average close to 1, and that spending-type shocks exceed tax/transfer multipliers by about 0.3–0.4 once study design is controlled for. Public investment is the most effective spending category, delivering multipliers 0.3–0.8 above undifferentiated spending; by contrast, sign-restriction approaches tend to yield 0.35 lower values and war-episode designs are comparatively ambiguous.

Fiscal multipliers vary across time and regions and are influenced by several structural characteristics of countries, including accumulated public debt, exchange rate regimes, and trade openness. For instance, countries with fixed exchange rate regimes often exhibit larger multipliers because monetary policy constraints amplify the effects of fiscal shocks (Corsetti et al., 2012). In contrast, economies that are more open to trade typically experience smaller multipliers, as fiscal expansions are partially offset by increased imports, reducing the impact of the stimulus on domestic demand (Ilzetzki et al., 2013). Furthermore, fiscal multipliers tend to be larger during economic downturns, when underutilized resources enable fiscal stimuli to have a greater impact (Auerbach and Gorodnichenko, 2012). They are also higher in regions with lower GDP per capita, such as Southern European countries, where multipliers can exceed 2.0 (Deleidi et al., 2020).

The literature on fiscal multipliers underscores the complexity and context-dependency of fiscal policy effects. While there is a consensus on the positive impact of government spending on GDP, the magnitude and dynamics of these effects are influenced by various factors, including the type of spending, economic conditions, and regional characteristics. As illustrated in Table 1, which focuses on government expenditure multipliers in the United States and Europe, estimates for the short-run impact of fiscal shocks generally hover around 0.3 to 1.3, although several studies report values as high as 3.5 or more under specific contexts. These wide-ranging results highlight the importance of both methodological differences (e.g., VAR vs. Local Projections, and their identification approach) and structural considerations such as the timing of expenditure or prevailing economic conditions. Future research should continue to explore these nuances to inform effective fiscal policy design, particularly in light of recent economic challenges such as the global recession following the coronavirus pandemic (International Monetary Fund, 2020). Table 1 reports multipliers for government expenditure (consumption and investment) G-type only. This aligns with our policy object—green public spending—implemented via public consumption and public investment (not tax cuts, transfers, or defence). Including other components of public spending (*e.g.,* military) would mix different mechanisms and identification settings, reducing comparability. After this table, we review the green-spending literature in detail.

While the macroeconomic effects of conventional public spending on GDP are well-established, the impact of green public expenditures on growth and labour markets has received less attention, despite its increasing importance. However, recent studies, have started to explore these effects, demonstrating that green public spending not only drives

Authors	Period and Region	Method	Impact	Peak	1	2	3
Auerbach and Gorodnichenko (2012)	1947:1–2009:2, US	VAR - BP	1.00	–	–	–	–
Blanchard and Perotti (2002)	1960:1–1997:4, US	VAR - BP	0.84	1.29	0.45	0.54	1.13
Burriel et al. (2010)	1981:1–2007:4, EU	VAR - BP	0.84	1.29	0.45	0.54	1.13
Caldara and Kamps (2017)	1950:1–2006:4, US	VAR - BP	1.0–1.3	–	–	–	–
Perotti (2004)	1980:1-2001:4, US	VAR - BP	–	–	0.31	–	0.10
Cimadomo and Bénassy-Quéré (2012)	1970:1-2009:4, US	VAR - BP	1.30	–	–	-0.73	–
Galí et al. (2007)	1960:1–2003:4, US	VAR - R	0.91	1.05	1.32	–	–
Bilbiie et al. (2008)	1957:1–1979:2, US	VAR - R	–	–	1.71	–	4.50
	1983:1–2004:3, US	VAR - R	–	–	0.94	–	2.38
Beetsma et al. (2008)	1970–2004, EU	VAR - R	1.17	1.50	1.50	1.19	–
Bachmann and Sims (2012)	1960:1–2011:1, US	VAR - R	0.84	0.84	–	–	–
Ellahie and Ricco (2017)	1959:1–2012:1, US	VAR - R	0.72	–	0.36	0.28	–
Mountford and Uhlig (2009)	1955:1–2000:4, US	VAR - SR	0.65	0.65	0.46	0.12	-0.22
Ben Zeev and Pappa (2017)	1947:1–2007:4, US	VAR - NA	–	–	–	2.14	–
Eichenbaum and Fisher (2004)	1974:1–2001:2, US	VAR - NA	–	–	0.61	0.28	0.21
Ramey and Shapiro (1998)	1947:1–1996:4, US	VAR - NA	+	–	–	–	–
Edelberg et al. (1999)	1948:1–1996:4, US	VAR - NA	1.10	3.50	–	–	–
Cavallo (2005)	1948:1–2002:4, US	VAR - NA	+	–	–	–	–
Ramey (2011b)	1939:1–2008:4, US	VAR - NA	–	0.6–1.2	–	–	–
Ramey (2011a)	1939:1–2008:4, US	VAR - NA	–	0.8–1.5	–	–	–
Auerbach and Gorodnichenko (2017)	1980–2017, panel 25 OECD	LP - BP	1.047	–	–	–	–
	1980–2017, panel 25 OECD	LP - FE	0.663	–	–	–	–
	1980–2017, panel 25 OECD	LP - NA	0.632	–	–	–	–
	1980–2017 (semiannual), panel 25 OECD	LP - BP	0.655	–	–	–	–
	1980–2017 (semiannual), panel 25 OECD	LP - FE	0.228	–	–	–	–
Riera-Crichton et al. (2015)	1986–2008 (semiannual), panel 29 OECD	LP - FE	0.31	–	0.40	–	–
Ramey and Zubairy (2018)	1889:1–2015:4, US	LP - BP	0.38	–	–	–	–
Ramey (2016)	1947:1–2015:5, US	LP - BP	0.37	–	–	–	0.39

Table 1: Summary of Government Spending Multipliers in the Global North (G-type only)- For a more systematic literature review, see Deleidi et al. (2023)
BP = Blanchard and Perotti identification strategy; FE = forecast error of the rate of growth of government spending; NA = narrative approach; R = Recursive approach; SR = Sign Restrictions; LP = Local Projection; VAR = Vector autoregression.

economic growth but also promotes sustainable development and addresses key labour market issues. Many of these works rely solely on microdata, focusing on the US economy or specific case studies. In this line, O'Callaghan et al. (2022) and the OECD (2017) highlight the broader macroeconomic benefits of green fiscal spending, including job creation and higher fiscal multipliers. Both works highlighted significant gaps in empirical studies regarding the evaluation of these policies.

Among the works looking at the impact of green spending, Batini et al. (2022) assessed GDP responses to green public investments using a FAVAR model on a dataset from 14 countries provided by the International Energy Agency. Their findings indicate that green investment multipliers range between 1.11 and 1.19, significantly outperforming non-green expenditures, which range between 0.52 and 0.65. Similarly, Hasna (2021) estimated local multipliers for green energy investments in the United States using state-level data from 2005 to 2021. Employing a Local-Projections approach, the study found multipliers between 1.1 and 4.2. Moreover, green expenditure demonstrated a robust labour market impact, generating 3.2 jobs per $100,000 invested initially, increasing to 7.4 jobs after two years.

Pollitt et al. (2021) utilized the macroeconometric E3ME model to evaluate the economic effects of Green Recovery Plans (GRPs). Results demonstrated GDP multipliers between 1.1 and 1.4, with sectors like renewables and electric vehicles driving growth. Additionally, GRPs spending was associated with significant job creation and productivity gains in high-value green technology sectors. Popp et al. (2020) use an event-study model to evaluate the employment multipliers of the American Recovery and Reinvestment Act (ARRA). Their results suggest that for every 1 million in green ARRA spending, 15 new jobs were created in the period following ARRA (2013-2017), with no significant short-term job gains observed.

Garret-Peltier (2017) employs a novel method based on Input-Output (I-O) tables to construct synthetic sectors for green and brown energy, which are traditionally not separated in conventional I-O tables. The results show that 1 million spent in the fossil fuel sectors creates 2.65 full-time jobs, whereas the same amount spent in the clean energy sectors creates between 7.49 and 7.72 jobs. Therefore, shifting 1 million from fossil fuels to clean energy results in a net increase of five jobs. Vona et al. (2019) use data from local labour markets in the US from 2006 to 2014 in an instrumental variable approach. Their findings show that for each additional green job created, about 4.2 new local jobs are generated in non-tradable and non-green sectors. Further supporting evidence from the World Resources Institute (Jaeger et al., 2021) highlights the superior job creation potential of green investments. For example, building efficiency measures create 2.8 times as many jobs per $1 million spent compared to fossil fuel investments, while ecosystem restoration generates 3.7 times as many jobs as oil and gas production. Similarly, investments in solar photovoltaic and wind energy result in 1.5 and 1.2 times more jobs, respectively, compared to equivalent spending in fossil fuel sectors. These findings highlight the potential of green fiscal policies to generate inclusive growth by creating jobs, enhancing productivity, and improving distribution, while also contributing to long-term environmental and economic resilience.

Despite these advancements, several gaps persist in the literature:

- Limited econometric studies on the macroeconomic effects of green public expenditure in Europe.
- Insufficient analysis of how structural differences between countries influence green spending spillovers.
- Lack of clarity on the distinct roles of green consumption and green investment in determining outcomes.
- Inadequate country-specific multiplier data to capture heterogeneous impacts across regions.
- Scarce exploration of the cumulative effects of green public spending.

This article aims to bridge these gaps by examining regional disparities and the composition of green public spending in shaping spillover effects within the European context.

2 Data and methodology

This section is dedicated to the data and methodology we used for our analysis.

2.1 Ontological perspectives on green investment

The concept of green investment in Europe is characterized by significant ontological divergence, reflecting a lack of consensus on its precise definition. While the European Parliament (2020) notes this definitional ambiguity, the OECD (2012) highlights the challenges of operationalizing green investment within a flexible and dynamic framework. To address the need for a clear framework, the EU Taxonomy for Sustainable Activities, developed by the Technical Expert Group in 2020, provides a structured categorization of green investments. These are defined as financial flows that contribute significantly to one or more of six key environmental objectives — climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems — without causing harm to other sustainability goals. By aligning investments with these objectives, the taxonomy aims to ensure that financial activities support sustainability goals without compromising other critical environmental or social priorities. Despite this, the debate surrounding the scope of green investment remains unresolved, with critical discussions focusing on whether public expenditures, such as subsidies for renewable energy, and fixed capital investments should be encompassed under its ambit. This debate extends to terminological precision, particularly the differentiation between "green public spending" and "green public investment" (European Parliament, 2020).

To analyze green public expenditures in Europe,we adopt a statistically grounded definition of green public expenditure using Eurostat's government expenditure by function dataset (`gov_10a_exp`). We filter "COFOG Division 05 — Environmental protection" (code GF05) and split by ESA transaction into: (i) Public Environmental Consumption (item P3, government final consumption) and (ii) Public Environmental Investment (item P51G, gross fixed capital formation). For each of the six COFOG–05 groups listed in Table 2, we aggregate all P3 flows into G^{C}_{green} and all P.51g flows into G^{I}_{green}; their sum is $G^{tot}_{green} = G^{C}_{green} + G^{I}_{green}$.

COFOG–05 covers environmental protection[2] in six groups (see Table 2): waste management (05.1), waste water management (05.2), pollution abatement (05.3), protection of biodiversity and landscape (05.4), R&D for environmental protection (05.5), and environmental protection n.e.c. (05.6). Expenditures whose primary purpose is not environmental protection are recorded outside GF05 and are therefore excluded from our baseline perimeter to preserve consistency (e.g., water supply services under COFOG 06.3). Researchers wishing to broaden the perimeter may reclassify such borderline items, but this introduces discretion and weakens comparability (COFOG Manual, 2011). Monetary values are expressed in constant 2015 EUR using the GDP deflator, as detailed in Table 3.

[2] COFOG Division 05 provides a narrow and clean perimeter for *environmental protection*. Many climate-related items that are plausibly "green" sit elsewhere in COFOG (e.g., Div. 04, 06, 07, 08, 10—economic affairs, housing, transport), where programmes often bundle "green" and "brown" components (e.g., mixed transport subsidies, energy support with fossil inputs). Without project-level tags, separating the green share from the brown share in these divisions is not reproducible and risks classification error. We therefore use GF05 because it is harmonised across countries, available by ESA transaction (P.3 vs. P.51g) for a transparent consumption–investment split, and minimises contamination from non-green spending. This choice is conservative—it likely understates the total fiscal effort toward climate objectives—but improves cross-country comparability and identification.

COFOG code & label	Scope examples (per COFOG manual)
05.1 Waste management	Street sweeping; collection, transport, treatment and disposal of municipal and hazardous waste (including nuclear waste management)
05.2 Waste water management	Sewage networks (collectors, pipelines, pumps); operation and construction of wastewater treatment plants
05.3 Pollution abatement	Ambient air and climate protection; soil and groundwater protection; cleaning of water bodies; noise and vibration abatement; radiation protection
05.4 Protection of biodiversity and landscape	Species and habitat protection; management of parks and nature reserves; landscape and site restoration (e.g., mines and quarries)
05.5 R&D environmental protection	Applied research and experimental development related to environmental protection (performed by government or funded extramural units)
05.6 Environmental protection n.e.c.	General administration, regulation, statistics, information, and education on environmental protection not elsewhere classified

Source: COFOG Manual (2011).

Table 2: COFOG Division 05 categories and scope examples

2.2 Data and descriptive analysis

To detect the macroeconomic effects of green fiscal policies (G^{tot}_{green}, G^{C}_{green}, and G^{I}_{green}) we used yearly data provided by Eurostat[3] and the IMF database[4]. Our analysis is based on 30 European countries, the choice of the countries was based on data availability: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland. The analysis was conducted using yearly macroeconomic panel data considered for the 1995-2020 period[5]. The relatively short time frame is compensated by the relatively large number of countries studied. The variables of interest are: total green public expenditure[6], (G^{tot}_{green}), and its components, namely green public consumption and investment (G^{C}_{green} and G^{I}_{green}), GDP (Y), employment (λ_{tot}), labour productivity (φ_{labour}), and private investment (I_{priv}). Additionally, we use total public expenditure[7] (G^{tot}) and the long-term interest rate (i) as control variables. The economic variables are expressed in real terms and were deflated using the GDP deflator. The variables are at logarithmic levels. Details on the construction of the different variables and sources used are provided in Table 3.

[3]See https://ec.europa.eu/eurostat/data/database

[4]See https://data.imf.org/?sk=a0867067-d23c-4ebc-ad23-d3b015045405

[5]In terms of panel structure, our dataset is strongly balanced for all countries, except for Iceland (IS), where COFOG data on environmental expenditure start in 1998.

[6]Considered as the sum of green public consumption and green public investment.

[7]As the sum of total public consumption and public investment.

Variable	Source	Database code	Item	Unit	Comment
G^{tot}_{green}	Eurostat	$gov\_10a\_exp/GF05$	P3/P51G	Million eu, constant price 2015	Sum of green consumption and investment
G^{C}_{green}	Eurostat	$gov\_10a\_exp/GF05$	P3	Million eu, constant price 2015	Green public consumption
G^{I}_{green}	Eurostat	$gov\_10a\_exp/GF05$	P51G	Million eu, constant price 2015	Green public investment
Y	Eurostat	$nama\_10\_gdp$	B1GQ	Million eu, constant price 2015	
λ_{tot}	Eurostat	$nama\_10\_a10\_e$	THS_PER	Thousand persons	
φ_{labour}				eu/person	Calculated with Y and λ_{tot}
I_{priv}	IMF and Eurostat	IFS/gov_10a_exp	NFI_XDC and P51G	Million eu, constant price 2015	Difference between total GFCF and public GFCF
G^{tot}	Eurostat	gov_10a_exp	P3/P51G	Million eu, constant price 2015	Sum of public investment and consumption
i	Eurostat	$int_r t$	MCBY	Long term government bond yields	

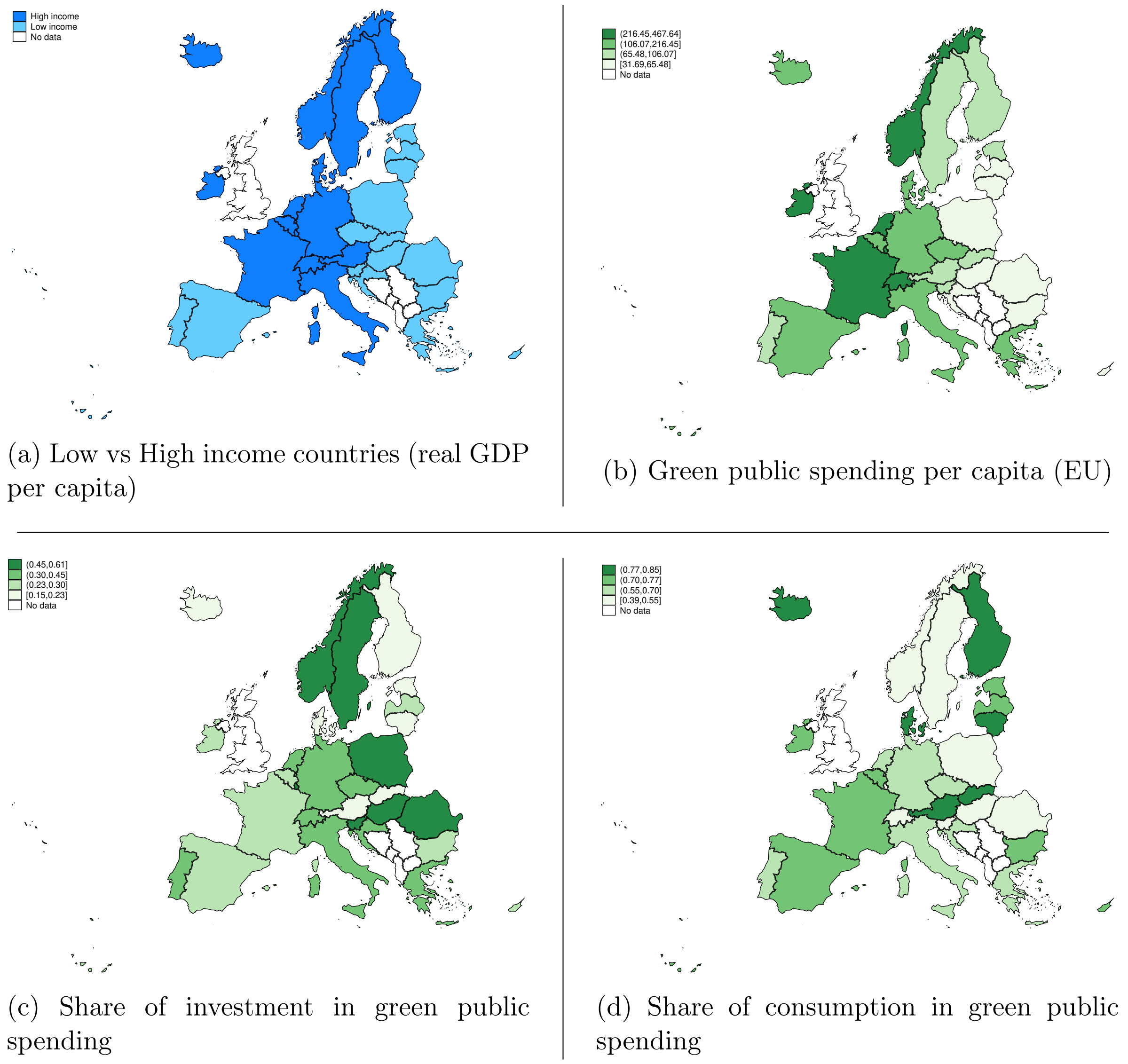
Table 3: Variables and description.

For simplicity—and because the literature lacks a widely accepted geographic partition(Gräbner and Hafele, 2020; Kersan-Škabić, 2020; Perez, 2019; Kohler, 2024)—we adopt an income-based grouping using real GDP per capita, which is highly stable over 1995–2020. To effectively capture the varying effects of green public expenditure on low- and high-income countries in Europe, we calculated the overall median GDP per capita in our dataset and created a dummy variable to classify countries as either above or below this threshold. Between 1995 and 2020, only Italy transitioned from the low- to the high-income category, underscoring the stability of European countries' positions in terms of GDP per capita. For Italy, we considered its most recent classification as a high-income country. Using this classification, we constructed the Map (a) in Figure (1).

Building on this observation, by computing the median of green public expenditure per capita across countries, we notice significant heterogeneity among European nations (see Figure 1, Map b). Specifically, the indicator exhibits extreme values across countries, with Romania recording the lowest per capita expenditure at 31.65 per capita, while the Netherlands registers the highest value at 467.64 per capita. The distribution of per capita expenditure indicates that high-income countries generally report higher ratios of green public spending per capita, although some variability exists among those countries.

To further examine the composition of this spending, we analyze the shares of investments (Figure 1, Map c) and consumption (Figure 1, Map d) relative to total green spending. Higher shares of investment are concentrated in northern and central European countries, including Scandinavia and parts of Central Europe (e.g., Germany and Austria), while southern and eastern European countries tend to show lower shares of green investment. A discernible clustering of higher investment shares aligns with economically stronger or more environmentally proactive nations in the north (see Figure 1, Map c).

In contrast, the share of green public spending allocated to consumption is higher in southern and western European countries, such as Spain, Portugal, and France. Northern and central European countries display relatively lower shares of green public spending devoted to consumption. This pattern suggests a potential emphasis on operational or short-term expenditures in the south, as opposed to longer-term investments in the north (see Figure 1 Map d).



(a) Low vs High income countries (real GDP per capita)

(b) Green public spending per capita (EU)

(c) Share of investment in green public spending

(d) Share of consumption in green public spending

Figure 1: Exploring the European divide (in real terms EU(2015) - own elabouration with Eurostat data)

2.3 Methodology

To evaluate the dynamic impact of green fiscal shocks (G^{tot}_{green}, G^{C}_{green}, and G^{I}_{green}) on key economic variables—GDP (Y), employment (λ_{tot}), productivity (φ_{labour}), and private investment (I_{priv})—we employ the Local Projections (LP) approach (Jordà, 2005). One of the critical aspects of this approach is the use of an appropriate identification strategy to isolate pure exogenous fiscal policy shocks. Specifically, we rely on a Structural Vector Autoregression (SVAR) model to identify fiscal policy shocks. Once identified, these shocks are introduced into the LP equation to assess their dynamic effects. Additionally, we extend our analysis by considering the Threshold Local Projections (T-LP) model, which allows us to explore potential nonlinearities in the response of economic variables to fiscal policy shocks.

In this section, we explore the methodological issues related to fiscal policy shocks. Section 2.3.1 discusses the identification of fiscal policy shocks, while Section 2.3.2 examines the exogeneity assumptions underlying these shocks. Finally, Section 2.3.3 outlines our adopted methodology, combining the LP approach and the T-LP model with structural shocks identified through the SVAR model.

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2.3.1 Identification

Both the SVAR and LP methodologies share a critical step: the identification of exogenous fiscal shocks, which is essential for distinguishing the causal effects of fiscal policies from endogeneity issues arising from their interaction with the broader macroeconomic environment. Identifying exogenous shocks is crucial to ensure meaningful and relevant data analysis. If the shocks are endogenous—arising as a reaction to other variables—it becomes impossible to disentangle the causal relationships between variables. Therefore, to study the true effects of fiscal policy interventions, it is vital to isolate purely exogenous shocks. In the SVAR framework, four main identification strategies are widely used: i) recursive ordering (R), as in Bachmann and Sims (2012); ii) the Blanchard and Perotti (BP) method, which introduces external parameters to model the relationship between taxes and output (Blanchard and Perotti, 2002); iii) the sign-restrictions approach (SR)(Mountford and Uhlig, 2009); and iv) the narrative approach (NA) (Ramey, 2011c; Alesina et al., 2012).

The first strategy, the recursive approach (R), relies on zero restrictions to resolve the endogeneity issue by applying a Cholesky decomposition (Bachmann and Sims, 2012). This method assumes a specific ordering of variables in the VAR model, where certain variables are contemporaneously unaffected by others, thereby allowing the structural shocks to be identified. Building on this approach, the Blanchard and Perotti (BP) method introduces additional parameters to explicitly model the contemporaneous relationship between taxes and output. These parameters are derived from institutional knowledge, such as information about tax collection lags or government spending mechanisms, to estimate the direct impact of fiscal policy interventions (Blanchard and Perotti, 2002).

The third strategy, the sign-restriction approach (SR), identifies exogenous fiscal shocks by imposing restrictions on the signs of the impulse response functions. Unlike the previous methods, this approach does not require precise parameter estimates; instead, it relies on theoretical assumptions about the expected direction of responses to fiscal shocks (e.g., a positive government spending shock increases output). This method provides more flexibility but depends heavily on the validity of the imposed sign restrictions (Mountford and Uhlig, 2009).

Finally, the narrative approach (NA) combines VAR models with dummy variables that capture exogenous fiscal episodes, such as policy changes driven by non-economic factors (e.g., wars or significant fiscal policy overhauls). These episodes are qualitatively assessed and assumed to be uncorrelated with the business cycle, ensuring that they represent genuine exogenous shocks. This method allows for a more subjective but targeted identification of fiscal interventions (Ramey, 2011c; Alesina et al., 2012).

In the LP framework, exogenous shocks are identified using alternative measures, such as changes in military spending, variations in public investment, forecast errors in fiscal variables, or narratively identified fiscal episodes. These methods leverage external data or qualitative insights to isolate fiscal shocks from endogenous dynamics within the economy (Auerbach and Gorodnichenko, 2017; Ramey and Zubairy, 2018).

2.3.2 Exogeneity of fiscal shocks

As already mentioned before, in order to get robust, coherent and analyzable estimations, it is of the utmost importance to analyse pure exogenous fiscal shocks. Otherwise, the analysis would have a possible endogeneity bias. The exogeneity of public fiscal policy has to be drawn by doing a distinction between automatic and discretionary fiscal policy

(Bernoth et al., 2015). Since we use every year records on a large pattern of European countries, our goal is thus to evaluate whether or not green public expenditure may be taken into consideration independently of the GDP growth rate in the year. Considering general fiscal and monetary policies, it is important to specify institutional and political factors which might also additionally have an effect on economic coverage decisions. Usually, economic government are not prompted to put into effect discretionary economic guidelines on every occasion there may be a cyclical fluctuation of GDP. Fiscal authorities' actions depend on the movement of economic coverage and automatic stabilizers.

Especially, the inclination for involvement of monetary policy has been defended by highlighting that a discretionary monetary policy could be executed more expeditiously than a decision on fiscal policy. Monetary policy is considerably less susceptible to implementation delays than fiscal policy, and it is much more agile than fiscal policy, particularly when it comes to reversing policy actions (Fontana and Sawyer, 2016)[8]. In addition, Taylor (2000) has shown that the correlation between discretionary fiscal measures and economic fluctuations is weaker compared to the link between automatic stabilizers and the cycle. These claims suggest that fiscal policy is less effective as a counter-cyclical instrument. Consequently, fiscal authorities tend to take discretionary actions only in response to significant and enduring shifts in output levels or broader macroeconomic conditions. Moreover, the econometric literature provides evidence of the exogeneity of fiscal policies, both with quarterly and annual data (Beetsma et al. (2009) and Born and Müller (2012).

These arguments are all the more true when considering green investments for several reasons. We can reasonably state that green investments are triggered by the empirical evidence of the anthropogenic nature of climate change IPCC (2014, 2021) and biodiversity extinction (IPBES-IPCC, 2021; Díaz et al., 2019). Moreover, the notion of the "EKC" or "environmental Kuznets curve" proposes that as economies progress and shift towards information-based industries and services, as well as relocation of manufacturing operations, greater awareness of environmental issues, and stricter enforcement of environmental regulations, there should be an increase in environmental expenditures and a gradual decrease in environmental degradation. Nonetheless, the theoretical foundations of the EKC have been the subject of extensive discussion and analysis (Stern, 2004). Even if certain economic conditions may reinforce them, the main purposes of green investments should be the decarbonisation of the economy, the protection of the environment or the pollution abatement. As a matter of fact, these incentives are disconnected from usual economic reasoning. The intention of a green policy is not to react to a bad economic health of the society, but to achieve new ecological standards in order to be in phase with the Paris Agreement. They are thus discretionary and do not come as a response to economic fluctuations. Green fiscal shocks can therefore be justified as exogenous to domestic business cycles because they are driven by international climate commitments, such as the Paris Agreement, which compel signatory nations to adopt binding emissions targets irrespective of short-term economic conditions. By anchoring fiscal

[8] In this line, (Deleidi et al., 2020, p.5) argues that: *"This argument is strengthened by the way in which monetary policy has been conducted in the last few years and by the fact that discretionary fiscal stimulus has been effected when monetary policy became powerless in boosting the economic activity. For example, at the beginning of one of the major economic crises of the last decades in 2008, the European Central Bank and other worldwide central banks (e.g., the FED), implemented expansionary monetary policies before the implementation of discretionary fiscal policies by governments. More specifically, it was only when the Zero Lower Bound was reached by monetary authorities that fiscal authorities acted with a set of discretionary instruments for boosting the depressed economic activity"*.

measures in multilateral cooperation frameworks—rather than contemporaneous macroeconomic performance—such shocks reflect external institutional obligations, attenuating concerns of reverse causality or endogenous policy responses to domestic demand fluctuations. This global-institutional driver disentangles green investment decisions from cyclical economic pressures, bolstering their identification as structural, externally motivated interventions. One may reasonably argue that exceptional programmes—such as the EU's 2020 NextGenerationEU/Recovery and Resilience Facility and the United States' 2022 Inflation Reduction Act—carry countercyclical elements, insofar as climate-related outlays were also mobilised for macro-stabilisation in the wake of the COVID-19 shock. To ensure our identification does not hinge on such conjunctural policies, we re-estimated all specifications excluding 2020; coefficients and inference are virtually unchanged. Additionally, we conducted panel Granger causality tests to assess the weak exogeneity of the identified fiscal shocks. The results provide no significant evidence that GDP—either contemporaneous or one-year-ahead—Granger-causes the shocks, for total, investment, and consumption components of green expenditure. Full test statistics and p-values are available upon request

2.3.3 Empirical approach

To evaluate the dynamic impact of green fiscal shocks (G^{tot}_{green}, G^{C}_{green} and G^{I}_{green}) on key economic variables, namely GDP (Y), employment (λ_{tot}), productivity (φ_{labour}), and private investment (I_{priv}), we apply the Local Projections (LP) approach Jordà (2005). One of the critical aspects of the LP approach is the use of an appropriate identification strategy to isolate pure exogenous fiscal policy shocks. Specifically, we identify green government spending shocks associated with G^{tot}_{green} and its components, G^{C}_{green} and G^{I}_{green}, within a panel VAR model, and then introduce them into the LP equation. Consistent with the literature on fiscal policy, government spending shocks are identified under the assumption that government spending does not respond contemporaneously to macroeconomic conditions (Blanchard and Perotti, 2002; Perotti, 2004) . Specifically, green public expenditures (G^{tot}_{green}) and its components, G^{C}_{green} and G^{I}_{green} are assumed to be unaffected contemporaneously by GDP. As highlighted in Section 2.3.2, this is particularly relevant for green public expenditure, since the corresponding fiscal shocks emanate from binding international climate commitments rather than from short-term domestic economic fluctuations.

Thus, structural shocks ($shock_{i,t}$) associated with G^{tot}_{green} are derived from the residuals ($w^{tot}_{green,i,t}$) of the first equation in a VAR model:

$$G^{tot}_{green,i,t} = \alpha_i + \delta_\tau + \beta_1 G^{tot}_{green,i,t-1} + \beta_2 Y_{i,t-1} + \beta_3 G^{tot}_{i,t-1} + \beta_4 i_{i,t-1} + w^{tot}_{green,i,t} \tag{1}$$

where total green public expenditure ($G^{tot}_{green,i,t}$) is regressed on its one-year lagged value ($G^{tot}_{green,i,t-1}$), the lagged value of the GDP ($Y_{i,t-1}$), non-green government spending ($G^{tot}_{i,t-1}$), and the lagged value of long term interest rate ($i_{i,t-1}$). Furthermore, the model includes country and time-fixed effects (α_i and δ_t).[9]

[9] The same procedure is applied to identify the spending shocks associated to green public consumption and investment (G^{C}_{green} and G^{I}_{green}). It should be noted that the correlation between the two reduced-form fiscal shocks is very low, thus their ordering is immaterial to the key results, as stated by (Perotti, 2004). A potential limitation of our identification strategy relates to fiscal foresight. We cannot explicitly account for foresight effects due to the absence of systematic data on expectations for green expenditure. However, the literature suggests that their omission may not significantly bias our results. Sims (2012) and Perotti (2014) argue that impulse responses obtained without modeling expectations closely resemble those including them. Furthermore, the use of annual data—as in our setting—helps mitigate the impact of anticipation effects (Auerbach and Gorodnichenko, 2017).

$$shock_{i,t} = w^{tot}_{green,i,t} \cdot \frac{G^{tot}_{green,i,t-1}}{y_{i,t-1}} \tag{2}$$

This approach ensures that potential biases from relying on a constant sample average are avoided (Owyang et al., 2013)[10]. In this way, the coefficients estimated in the LP equations can be directly interpreted as multipliers. We follow this logic and apply it to our context of a heterogeneous panel of countries, which display markedly different expenditure-to-GDP ratios.

Once the spending shocks ($\text{shock}_{i,t}$) are identified, they are introduced into the Local Projection (LP) equation to estimate the impulse response functions (IRFs)[11] . The LP computes individual regressions for each variable of interest ($y_{i,t+h}$) at each horizon h following the realization of the shock:

$$y_{i,t+h} = \alpha_i + \delta_\tau + \beta^h \text{shock}_{i,t} + \theta_1^h z_{i,t-1} + \epsilon_{i,t+h} \tag{3}$$

In Equation (3), we estimate a dynamic two-way fixed-effect model where α_i and δ_τ denote country and time fixed effects, respectively. The dependent variable y represents the variable of interest (Y, λ_{tot}, φ_{labour}, or I_{priv}) evaluated at each horizon $h = 0, 1, \ldots, H$. The term $\text{shock}_{i,t}$ refers to the identified green fiscal shocks, and $z_{i,t-1}$ includes a set of control variables lagged by one year. These include $G^{\text{tot}}_{\text{green}}$, Y, i, and our variables of interest, all lagged by one period to match the annual frequency of the data[12] . The error term is denoted by $\epsilon_{i,t+h}$.

To investigate potential nonlinearities in the transmission of green public expenditure ($G^{\text{tot}}_{\text{green}}$) and its components ($G^{C}_{\text{green}}$ and G^{I}_{green}), we extend the baseline model in Equation (3) by estimating a Threshold Local Projections (T-LP) model. Two sources of nonlinearity are considered.

First, we assess whether the effects of green public expenditure differ between countries classified as High-Income (HI) and Low-Income (LI). We define a time-invariant[13] dummy variable D_i^{LI} such that:

[10] As Owyang et al. (2013)[p.131] point out, the traditional VAR literature often relies on an ad hoc conversion factor based on the sample average of Y/G, which can generate biased multipliers since this ratio fluctuates substantially over time and may lead to implausibly large estimates. To address this issue, they propose using the value of G/Yat each point in time rather than the average over the entire sample, thereby ensuring that the coefficients from the output and spending equations are expressed in the same units—an essential requirement for the proper construction of fiscal multipliers. Another approach to circumvent potential biases is applied byRamey and Zubairy (2018) following Gordon and Krenn (2010).They divide all variables by a measure of the trend or potential GDP. However, this approach has been questioned because potential output is sensitive to business cycle fluctuations (Auerbach and Gorodnichenko, 2017; Coibion et al., 2017)

[11] As Ramey and Zubairy (2018) state, the Blanchard-Perotti identification is equivalent to using current government spending directly as the fiscal shock within the LP specification, provided that the set of control variables is the same in both the identification step and the LP regression. In our context, the approach we adopt provides the additional flexibility of the LP framework, which is particularly valuable as we analyse the effects of green public spending on multiple economic variables included as controls in the LP equations.

[12] The inclusion of the interest rate allows the Blanchard and Perotti identification strategy to be extended to consider the interaction between monetary and fiscal policies. Additionally, net taxes are not included in the specified models since scholarly-based literature has shown that they do not lead to model misspecifications and thus do not alter the estimates of spending multipliers(Auerbach and Gorodnichenko, 2017; Ramey and Zubairy, 2018).

[13] Between 1995 and 2020, looking at the yearly sample median, only Italy transitioned from the low- to the high-income category, underscoring the stability of European countries' positions in terms of GDP per capita. For Italy, we considered its most recent classification as a high-income country.

$$D_i^{\mathrm{LI}} = \begin{cases} 1 & \text{if country } i \text{ has GDP per capita below the sample median} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

We then estimate the following equation:

$$\begin{aligned} y_{i,t+h} = \alpha_i + \delta_\tau + D_i^{\mathrm{LI}} \cdot \beta_{\mathrm{LI}}^h \cdot \mathrm{shock}_{i,t} + D_i^{\mathrm{LI}} \cdot \theta_{1,\mathrm{LI}}^h \cdot z_{i,t-1} \\ + (1 - D_i^{\mathrm{LI}}) \cdot \beta_{\mathrm{HI}}^h \cdot \mathrm{shock}_{i,t} + (1 - D_i^{\mathrm{LI}}) \cdot \theta_{1,\mathrm{HI}}^h \cdot z_{i,t-1} + \epsilon_{i,t+h} \end{aligned} \tag{5}$$

Here, the subscripts LI and HI indicate the low-income and high-income regimes, respectively.

Second, we examine whether the effects of green public spending differ between countries with a high versus low share of green public consumption relative to total green public expenditure. To do so, we define a time-varying dummy variable $D_{i,t}^{\mathrm{LS}}$ as:

$$D_{i,t}^{\mathrm{LS}} = \begin{cases} 1 & \text{if the share } \dfrac{G_{green}^{C}}{G_{green}^{tot}} \text{ in country } i \text{ at time } t \text{ is below the yearly sample median} \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

We then re-estimate Equation (5) by replacing D_i^{LI} with $D_{i,t}^{\mathrm{LS}}$ to allow responses to differ by green expenditure composition.

For all estimated models, we also calculate the cumulative effects, which allow us to study the response of our variables of interest per unit increase in (G_{green}^{tot}, G_{green}^{C}, and G_{green}^{I}). Impulse response functions (IRFs) and cumulative multipliers are calculated over a horizon of four years (from t to $t+4$).

3 Results

In this section, we present the estimated Impulse Response Functions (IRFs) and cumulative effects, illustrating the responses of GDP (Y), employment (λ_{tot}), labour productivity (φ_{labour}), and private investment (I_{priv}) to total green public spending (G_{green}^{tot}) and its components: green public consumption and investment (G_{green}^{C} and G_{green}^{I}). The analysis is based on local projections evaluated over a four-year horizon ($h = 4$).

In the figures below, we show the estimated IRFs, which capture the dynamic responses of the variables of interest to green spending shocks, while in the Tables, we report the cumulative coefficients summarizing the total effects over the evaluation horizon. [14] Statistically significant estimates are highlighted in bold. The reported results quantify the impacts on GDP and private investment as multipliers, measure employment effects as the number of jobs generated per €100,000 of green public spending, and express productivity effects through elasticities.

Section 3.1 provides an overview of the aggregate effects across Europe, while Section 3.2 examines the European divide in green public spending. Finally, Section 3.3 explores the compositional influence of green public spending, focusing on the impacts of G_{green}^{C} and G_{green}^{I}.

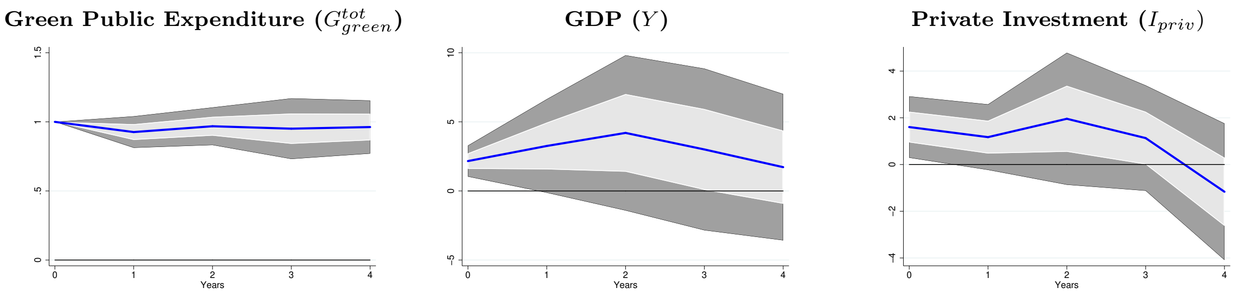
[14] Cumulative multipliers are calculated by dividing the cumulative response of the variable of interest y (Y, λ_{tot}, φ_{labour}, and I_{priv}) by the cumulative change in green government expenditure (G_{green}^{tot}, G_{green}^{C}, and G_{green}^{I}) that occurred from 0 to 4 years after the shocks. In addition, we also report the peak effects, defined as the highest value of the ratio between the change in the variable of interest y (over the 0–4-year horizon) and the initial change in green government expenditure.

3.1 Aggregate Effects Across Europe

This section presents the socio-economic effects of green public spending across all European countries, analyzing first total green public expenditure, and then both green investment, and green consumption. By examining these components separately, the analysis provides a comprehensive overview of their macroeconomic implications, highlighting both their distinct contributions and their overall influence on economic performance.

The results illustrate the positive macroeconomic impacts of green public expenditure shocks (G^{tot}_{green}) for Europe. The shaded areas in the graphs represent the 68% and 95% confidence intervals, providing statistical evidence for the observed effects. Impulse response functions (Figure 2) reveal that (G^{tot}_{green}) significantly enhances GDP levels (Y), private investment (I_{priv}), total employment (λ_{tot}) and labour productivity (φ_{labour}) over a four-year horizon. The table of cumulative effects further supports these findings, with significant estimates (68% confidence interval, indicated in bold) showing robust impacts across all variables.

In the first year, green public spending generates a GDP multiplier (Y) of 2.81 and creates 3.63 jobs (λ_{tot}) per €100,000 of total green public expenditure. Over the four years following the shock, the average GDP multiplier (Y) rises to 2.91, while job creation (λ_{tot}) averages 3.82 jobs per €100,000. Private investment (I_{priv}) also shows sustained positive effects, reaching a value of 1.44 in year two, indicating a crowding-in effect. Furthermore, labour productivity (φ_{labour}) improves modestly but consistently, with significant cumulative effects observed throughout the period.



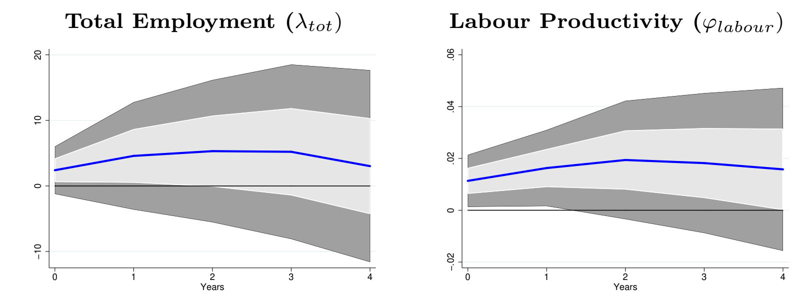


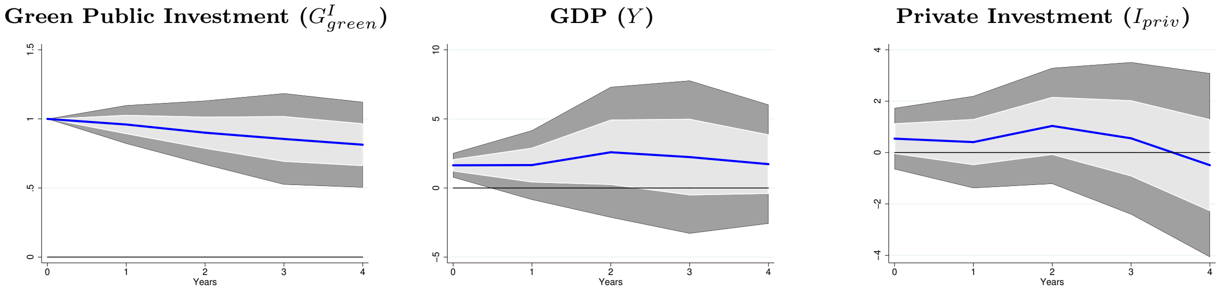
Table of Estimates

	Year 0	Year 1	Year 2	Year 3
Y	**2.16**	**2.81**	**3.32**	**3.28**
I_{priv}	**1.60**	**1.44**	**1.64**	**1.53**
λ_{tot}	**2.40**	**3.63**	4.25	4.55
φ_{labour}	**0.011**	**0.014**	**0.016**	**0.017**

	Year 4	Mean	Peak
Y	2.98	2.91	4.21
I_{priv}	0.98	1.44	1.96
λ_{tot}	4.27	3.82	5.31
φ_{labour}	**0.017**	0.015	0.019

Figure 2: Impulse Response Functions of Green Public Expenditure (G^{tot}_{green}). The shaded areas represent 68% and 95% confidence intervals. In Tables of Estimate we report the cumulative effects. Significant estimates are in bold (68%).

These findings highlight the significant economic potential of green public expenditure, showcasing its capacity to stimulate economic growth, enhance private sector activity, and strengthen labour market performance. The GDP multipliers for green spending observed in our analysis exceed typical fiscal multipliers and align closely with the estimates provided by Hasna (2021), who report values ranging between 1.1 and 4.2 for the United States. Similarly, Batini et al. (2022), using a FAVAR model on a panel of 14 countries, demonstrate that green multipliers consistently surpass those associated with non-green public expenditure. Corroborating these results, O'Callaghan et al. (2022) emphasize that green fiscal spending not only achieves higher multipliers but also generates greater employment gains compared to non-green investments. Building upon this consideration, it is worth noting that Rutskiy and Osipenko (2020) also identified a positive impact of green public expenditure on labour productivity in Europe. Their findings suggest that investments in pollution control and clean technologies lead to a 0.023% rise in productivity for every 1% increase in expenditure. These converging findings further reinforce the case for prioritizing green public investments as an effective tool for economic recovery and sustainable growth.



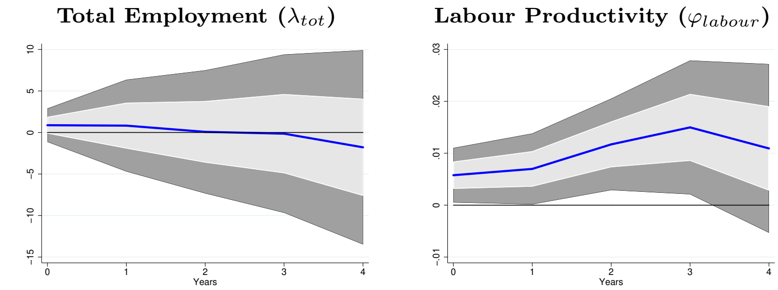


Table of Estimates

	Year 0	Year 1	Year 2	Year 3
Y	**1.64**	**1.69**	**2.06**	2.19
I_{priv}	0.54	0.48	0.69	0.68
λ_{tot}	0.88	0.87	0.62	0.44
φ_{labour}	**0.006**	**0.007**	**0.009**	**0.011**

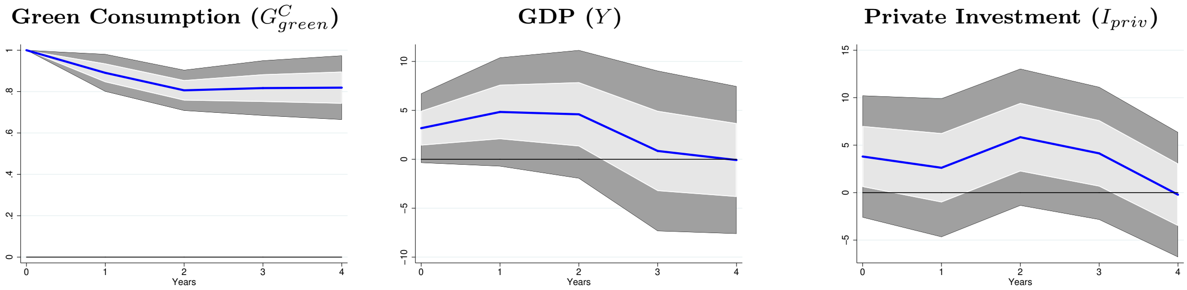
	Year 4	Mean	Peak
Y	2.18	1.95	2.59
I_{priv}	0.45	0.57	1.03
λ_{tot}	-0.03	0.55	0.82
φ_{labour}	**0.011**	0.009	0.015

Figure 3: Impulse Response Functions of Green Public Investment (G^I_{green}). The shaded areas represent 68% and 95% confidence intervals. In Tables of Estimate we report the cumulative effects. Significant estimates are in bold (68%).

The compositional analysis of green public spending focuses on its two primary components: green public investment (G^I_{green}) and green public consumption (G^C_{green}). Examining their significant macroeconomic effects, this section highlights their distinct contributions and potential complementarities in shaping economic performance.

Green public investment (G^I_{green}), as illustrated in Figure 3, exhibits a significant positive impact on GDP (Y) and private investment (I_{priv}). The GDP multiplier (Y) reaches a statistically significant value of 1.69 in the first year and reaching a value at 2.06 in the second year (Table of Estimates, Figure 3). The effect on employment (λ_{tot}) is significantly positive for the first three years, with a strong cumulative effect. Private investment (I_{priv}) also responds positively, but the results are not statistically significant. However, the impacts on labour productivity φ_{labour} are more modest, with only marginally significant increases early in the observed period. These results suggest that green investment plays a crucial role in fostering economic growth and stimulating private sector activity over the medium term.

In contrast, green public consumption (G^C_{green}), shown in Figure 4, demonstrates stronger and more immediate significant effects. The GDP multiplier reaches 4.24 in the first year and reaching a value of 4.68 in the second year, both statistically significant (Table of Estimates, Figure 4). Private investment also experiences substantial and significant gains, with a multiplier effect of 4.55 in the second year. Employment effects are



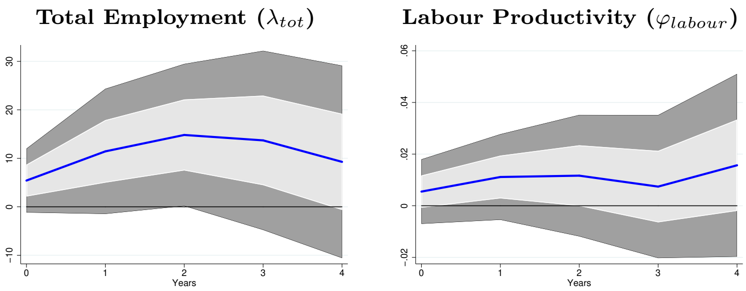


Table of Estimates

	Year 0	Year 1	Year 2	Year 3
Y	**3.18**	**4.24**	**4.68**	3.83
I_{priv}	**3.80**	3.40	**4.55**	**4.67**
λ_{tot}	**5.41**	**8.91**	**11.74**	**12.91**
φ_{labour}	0.005	**0.009**	**0.010**	0.010

	Year 4	Mean	Peak
Y	3.09	3.80	4.60
I_{priv}	3.73	4.03	5.84
λ_{tot}	12.61	10.32	14.80
φ_{labour}	0.012	0.009	0.012

Figure 4: Impulse Response Functions of Green Consumption (G^C_{green}). The shaded areas represent 68% and 95% confidence intervals In Tables of Estimate we report the cumulative effects. Significant estimates are in bold (68%).

particularly notable, with significant increases in job creation. Productivity impacts remain less pronounced but are statistically significant over the observed period, indicating gradual improvements.

These findings highlight the complementary nature of green public investment and consumption. While green investment significantly contributes to medium-term economic growth and private sector engagement, green consumption provides immediate and pronounced gains in GDP, employment, and private investment. The compositional differences suggest that policy frameworks should strategically balance both components to optimize the macroeconomic benefits of green public spending. As a robustness check, we re-estimated our models excluding the year 2020 to account for the exceptional fiscal measures adopted during the COVID-19 crisis. The results remain virtually unchanged, confirming that our findings are not driven by this extraordinary episode (see Appendix A, Table A1).

3.2 European Divide in Green Public Spending

This section examines the European divide in the macroeconomic impacts of green public spending by introducing a dummy variable to differentiate between high-income (blue line) and low-income countries (red line), defined as those above and below the median real GDP per capita over the period 1995–2020. The analysis focuses on the aggregate effects of total green public expenditure and its two components, green public investment and green public consumption, highlighting significant differences in their impacts across income groups.

The results reveal a clear divergence in the impacts of total green public expenditure (G^{tot}_{green}) between high-income and low-income countries (Figure 5). In high-income countries, the GDP multiplier (Y) reaches a significant 5.03 in the first year, with an average of 4.70 over the four years (Table 4). Employment (λ_{tot}) effects are similarly substantial, with significant increases of 5,40 jobs per €100,000 on average over the four-year period. These results underscore the strong capacity of green public spending in high-income countries to drive economic growth and labour market improvements.

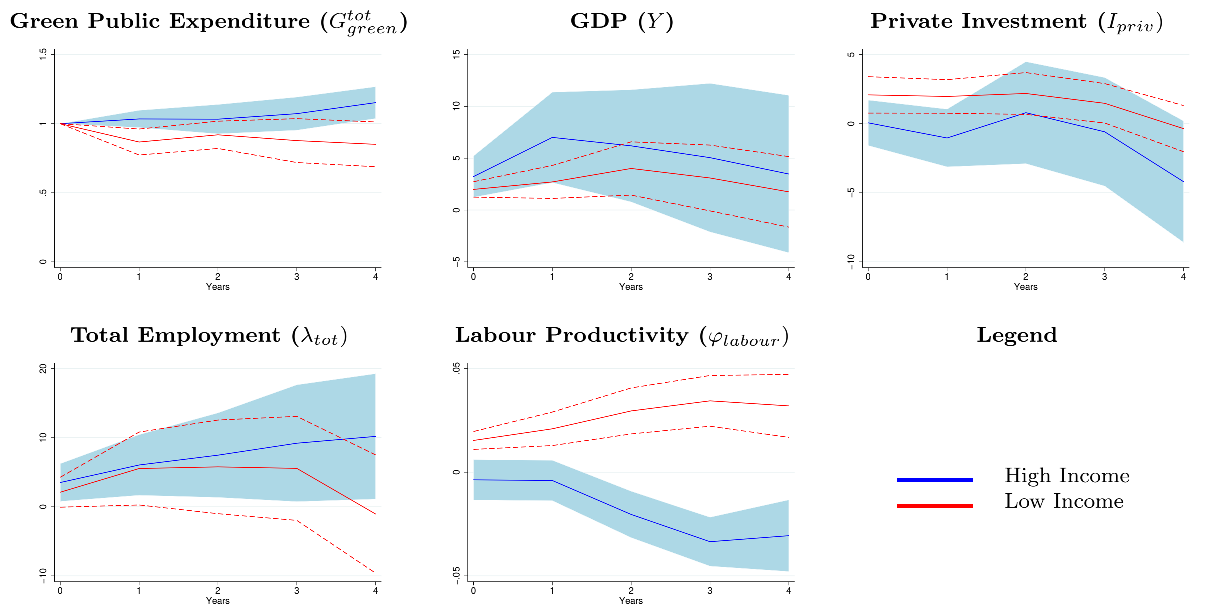


Figure 5: Impulse Response Functions of Green Public Expenditure (G^{tot}_{green}). The shaded areas represent 68% confidence intervals.

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low income							
Y	**1,99**	**2,52**	**3,13**	3,22	3,00	2,77	4,01
I_{priv}	**2,08**	**2,17**	**2,24**	**2,11**	1,63	2,05	2,18
λ_{tot}	**2,11**	**4,09**	4,82	5,18	3,97	4,03	5,77
φ_{labour}	**0,02**	**0,02**	**0,02**	**0,03**	**0,03**	0,02	0,03
High income							
Y	**3,23**	**5,03**	**5,36**	5,19	4,72	4,70	7,00
I_{priv}	0,06	-0,48	-0,06	-0,19	-0,94	-0,32	-4,20
λ_{tot}	**3,51**	**4,70**	**5,55**	**6,34**	**6,88**	5,40	10,19
φ_{labour}	0,00	0,00	**-0,01**	**-0,01**	**-0,02**	-0,01	-0,04

Table 4: Cumulative effects Green Public Expenditure (G^{tot}_{Green}). Significant estimates are in bold (68%).

In contrast, low-income countries experience more modest but significant GDP effects, with a multiplier of 2.52 in the first year, and an average of 2.77 over the four years. Employment (λ_{tot}) effects are similarly significant, with an average of 4.03 jobs created per €100,000. Notably, private investment (I_{priv}) responds positively in low-income countries, with significant effects of 2.17 in the first year and 2.24 in the second year, indicating a crowding-in effect. Contrary to high income countries, labour productivity (φ_{labour}) shows improvements for low income countries. This aligns with Fernández and Montuenga-Gómez (2003), who analyze Spain's public capital investments and demonstrate significant productivity growth, particularly in industrial sectors.

These findings highlight the differentiated macroeconomic impacts of green public spending across Europe, with high-income countries benefiting from stronger GDP and employment effects, while low-income countries experience more pronounced private investment responses. Southern Europe's dependence on external factors makes it less adaptable to policy changes, complicating the GDP response to green expenditure (Rodríguez-Pose and Fratesi, 2007). Low-income European countries tend to have higher import propensities, which means a significant portion of their green expenditure leaks out of the domestic economy through imports. This reduces the multiplier effect of green spending on GDP compared to high-income countries, where economies are more self-sufficient and can retain more of the expenditure within their borders. Stockhammer and Novas Otero (2023) emphasize that low-income countries relies more on fiscal-driven growth through public investments, unlike higher income Europe, which had prioritized innovation-led competitiveness. Kwilinski et al. (2023) indicates that spatial heterogeneity in green economic growth among EU countries suggests that green investments may yield better productivity outcomes in low-income European countries due to differing levels of technological efficiency and innovation adoption. This is in line with Feng et al. (2022) that have also shown that poorest European countries, which have historically under-invested in green infrastructure, experience substantial productivity gains from investments in renewable energy and environmental technology, as these fill critical infrastructure gaps and improve resource efficiency. This fiscal reliance amplifies the impact of green investments in the South. Low-income European countries may have more room for improvement in green technologies, leading to greater relative gains from greenfield investments. In contrast, high-income European countries may already have higher baseline efficiencies, resulting in diminishing returns from additional green investments.

The disaggregated analysis of green public investment (G^I_{green}) and green public consumption (G^C_{green}) further illustrates the European divide in their macroeconomic impacts.

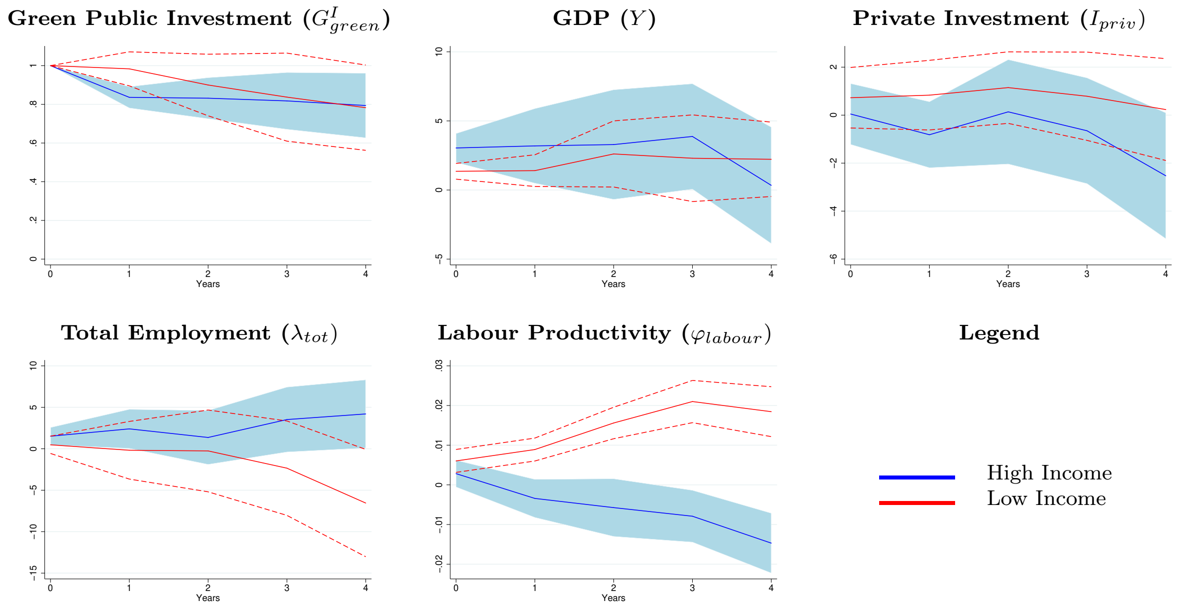


Figure 6: Impulse Response Functions of Green Public Investment (G^I_{green}). The shaded areas represent 68% confidence intervals.

For green public investment (G^I_{green}), high-income countries exhibit significant GDP effects, with a multiplier of 3.40 in the first year, with a peack effect of 3.87 in the fourth year (Figure 6, Table 5). Employment (λ_{total} effects are also notable, with an average of 2.24 jobs created per €100,000. Conversely, in low-income countries, GDP effects (Y) are more modest but significant, reaching 1.86 in the second year, while private investment estimates are not significant.

Green public consumption (G^C_{green}) demonstrates stronger immediate impacts, particularly in high-income countries, where the cumulative GDP (Y) multiplier reaches a significant 8.17 in the first year (Figure 7, Table 6). Employment effects (λ_{tot}) in high-income countries are particularly pronounced, with an average of 11.03 jobs created per

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low income							
Y	**1,36**	**1,39**	**1,86**	2,06	2,20	1,77	2,61
I_{priv}	0,73	0,79	0,94	0,94	0,83	0,84	1,15
λ_{tot}	0,48	0,15	0,01	-0,62	-1,96	-0,39	-6,50
φ_{labour}	**0,01**	**0,01**	0,01	**0,01**	**0,02**	0,01	0,02
High income							
Y	**3,04**	**3,40**	3,57	**3,84**	3,21	3,41	3,87
I_{priv}	0,05	-0,42	-0,24	-0,37	-0,89	-0,37	-2,50
λ_{tot}	**1,51**	**2,13**	1,98	2,52	3,04	2,24	4,20
φ_{labour}	0,00	0,00	0,00	**0,00**	**-0,01**	0,00	-0,02

Table 5: Cumulative effects Green Public Investment (G^{I}_{Green}). Significant estimates are in bold (68%).

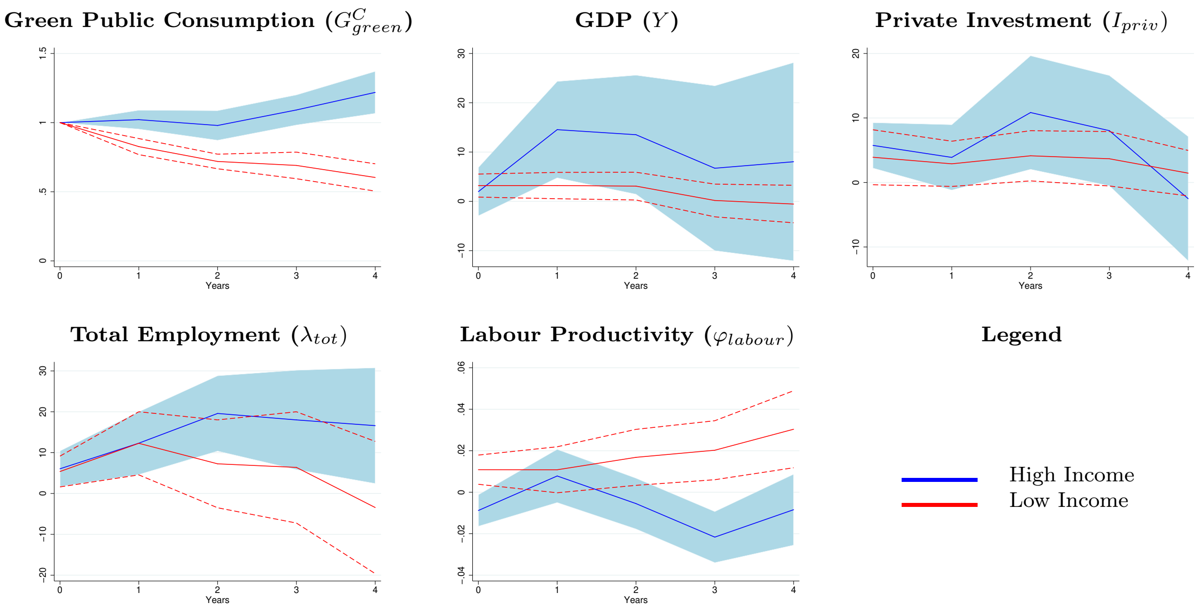


Figure 7: Impulse Response Functions of Green Public Consumption (G^{C}_{green}). The shaded areas represent 68% confidence intervals.

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low income							
Y	**3,20**	**3,51**	**3,73**	2,99	2,38	3,16	3,21
I_{priv}	4,18	**4,30**	**5,10**	**5,36**	4,95	4,78	5,13
λ_{tot}	**5,38**	**9,66**	9,79	9,67	7,26	8,35	12,28
φ_{labour}	**0,01**	0,01	**0,02**	**0,02**	**0,02**	0,02	0,03
High income							
Y	1,97	**8,17**	**10,01**	8,98	8,43	7,51	14,54
I_{priv}	**5,66**	4,57	**6,62**	6,76	4,71	5,66	10,61
λ_{tot}	**6,05**	**9,09**	**12,65**	**13,68**	**13,66**	11,03	19,60
φ_{labour}	**-0,01**	0,00	0,00	**-0,01**	**-0,01**	-0,01	-0,02

Table 6: Cumulative effects Green Public Consumption (G^{C}_{Green}). Significant estimates are in bold (68%).

€100,000. In low-income countries, while GDP effects (Y) remain significant (peaking at 3.21), the most striking impacts are observed in employment (λ_{tot}), with an average of 8.35 jobs created per €100,000.

The income-level divide underscores structural asymmetries. High-income economies leverage G^{I}_{green} for productivity-linked GDP persistence, while G^{C}_{green} drives demand-side surges in output and employment. Low-income economies derive limited medium-term gains from G^I_{green}, with G^C_{green} offering broader short-term stimulus. These findings highlight the role of institutional capacity and economic structure in shaping green fiscal policy efficacy. As a robustness check, we re-estimated the green spending shocks using a non-linear specification allowing the coefficients of the spending equation to vary across regimes (low- vs. high-income countries). The resulting shocks are highly correlated with those from the baseline linear specification, and the estimates reported in Tables A2-A4 (see Appendix A) are fully consistent with our main results.

3.3 Compositional Influence of Green Public Spending

This section examines how the composition of green public spending influences the respective macroeconomic impacts of green public investment (G^I_{Green}) and green public consumption (G^C_{Green}). To analyze this, countries are divided into two groups based on the share of green public consumption (G^C_{Green}) in total green public expenditure (G^{tot}_{Green}), using the median as the threshold to distinguish between high and low green consumption levels. The results focus on statistically significant findings, as indicated in bold in the tables.

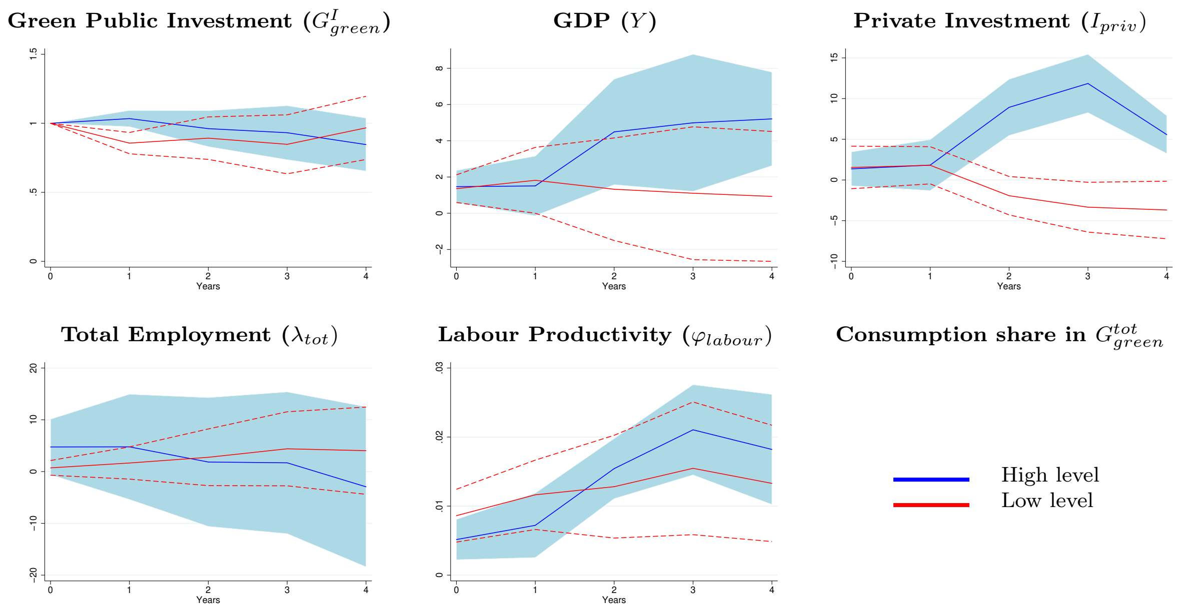


Figure 8: Impulse Response Functions of Green Public Investment (G^I_{green}). The shaded areas represent 68% confidence intervals.

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low level							
Y	**1,36**	**1,71**	1,64	1,56	1,43	1,54	1,81
I_{priv}	1,54	1,80	0,51	**-0,54**	**-1,23**	0,42	-3,68
λ_{tot}	0,72	1,28	1,87	2,65	2,97	1,90	4,39
φ_{labour}	**0,01**	0,01	**0,01**	**0,01**	**0,01**	0,01	0,01
High level							
Y	**1,47**	1,46	**2,49**	**3,17**	**3,70**	2,46	4,49
I_{priv}	1,37	1,57	**4,05**	**6,11**	**6,19**	3,86	11,86
λ_{tot}	4,76	4,69	3,80	3,33	2,12	3,74	4,77
φ_{labour}	**0,01**	**0,01**	**0,01**	**0,01**	**0,01**	0,01	0,02

Table 7: Cumulative effects Green Public Investment (G^I_{green}). Significant estimates are in bold (68%).

The analysis reveals that countries with a high share of green consumption in total green spending exhibit stronger and more significant macroeconomic impacts for green public investment (G^I_{Green})[15]. In these countries, the GDP multiplier (Y) averages 2.46 over the observed period, and private investment (I_{priv}) exhibits an average multiplier of 3.86 (Table 7). Employment effects (λ_{tot}) are positive yet not significant, whereas the impact of labour productivity (λ_{tot})is noticeably positive, persistent, and significant over the first four years after the shock. These results suggest that a higher share of green consumption facilitates a more effective translation of green investment into economic growth and improvements in the labour market.

Conversely, in countries with a low share of green consumption — high share of green investment —, green public investment (G^I_{Green}) demonstrates more modest impacts. The GDP multiplier (Y) averages 1.54, with private investment (I_{priv}) exhibiting a negative effect for years 3 and 4. The productivity effects (λ_{tot}) exhibit a positive impact of comparable magnitude to that observed in countries with a high proportion of green consumption within their total green public expenditure. These findings highlight the comparatively limited macroeconomic benefits of green investment in countries with lower green consumption shares, and the importance of green consumption in counteracting potential crowding-out effect of green investment on private investment.

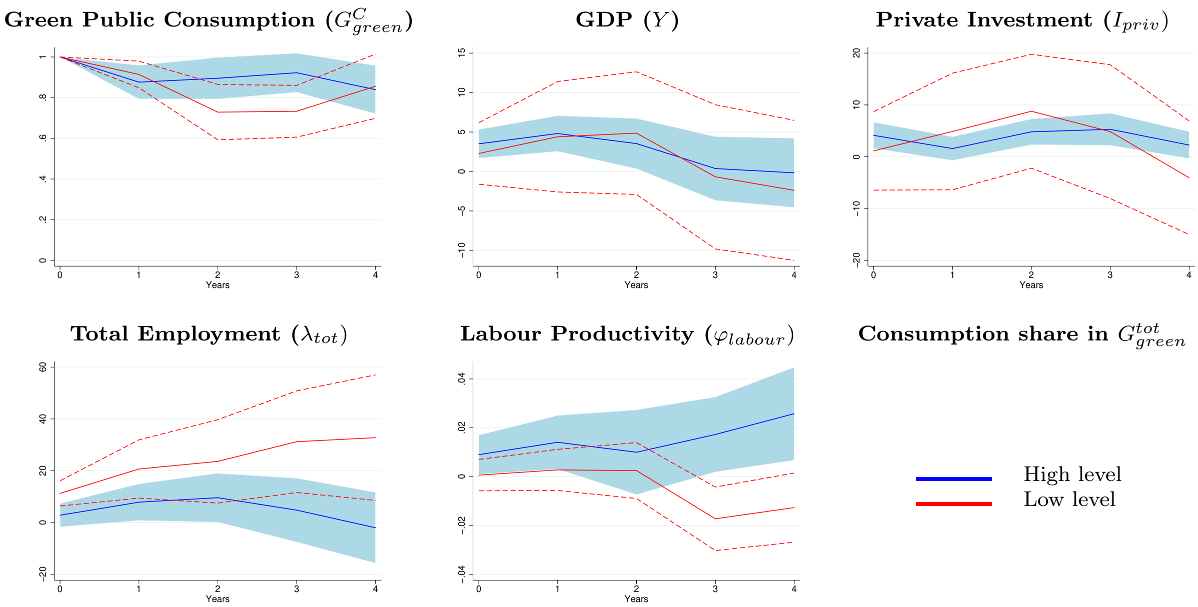


Figure 9: Impulse Response Functions of Green Public Consumption (G^C_{green}). The shaded areas represent 68% confidence intervals.

For green public consumption (G^C_{Green}), the results indicate that countries with a low share of green consumption in total green public expenditure experience stronger employment effects (Figure 9). Employment (λ_{tot}) increases significantly (Table 8). However, the GDP (Y) and private investment impacts (I_{priv}) are not significant.

In contrast, countries with a high share of green consumption exhibit significant GDP effects (Y), averaging 3.64 over the observed period. Private investment (I_{priv}) also responds positively, with an average multiplier of 4.05. The labour productivity effects (φ_{labour}) are notable more pronounced compared to low green consumption countries. These findings suggest that a high share of green consumption supports economic growth and private sector engagement while yielding moderate employment gains.

[15]See Figure 8

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low level							
Y	2,28	3,49	4,37	3,22	2,00	3,07	4,86
I_{priv}	1,51	3,44	5,92	6,27	4,17	4,26	9,01
λ_{tot}	**11,27**	**16,69**	**21,02**	**25,70**	**28,24**	20,58	31,00
φ_{labour}	0,00	0,00	**0,00**	0,00	-0,01	0,00	-0,01
High level							
Y	**3,51**	**4,43**	**4,28**	3,31	2,66	3,64	4,81
I_{priv}	**4,17**	3,29	**4,12**	**4,55**	4,14	4,05	5,38
λ_{tot}	2,84	5,71	7,32	7,79	5,09	5,55	9,58
φ_{labour}	**0,01**	**0,01**	0,01	**0,01**	**0,02**	0,01	0,03

Table 8: Cumulative effects Green Public Consumption (G^C_{green}). Significant estimates are in bold (68%).

The composition of green public spending — particularly its balance between consumption and investment — determines its macroeconomic effects. Hottenrott and Rexhäuser (2013) show, for instance, that in high-income countries, compliance-driven green innovations can crowd out non-green R&D activities. Firms often divert resources toward meeting environmental regulations, scaling down long-term R&D projects unrelated to production. However, the study also finds that subsidy-induced green innovations mitigate this crowding-out effect, indicating a nuanced relationship between green expenditure and innovation. Understanding these complementarities is crucial, as they help explain why certain sectors benefit more from green public spending while others may experience short-term trade-offs.

Overall, the results highlight the importance of balanced composition of green public spending in shaping its macroeconomic impacts. Countries with a higher share of green public consumption tend to amplify the effects of green public investment, particularly on GDP and private investment. Conversely, countries with a lower share of green consumption experience stronger employment effects from green public consumption but more modest impacts on GDP and private investment. We also conducted an additional robustness exercise by re-estimating the models with non-linear shocks that account for whether countries have a high or low share of green public consumption relative to total green public expenditure. The shocks remain highly correlated with those from the baseline specification, and the results shown in Tables A5 and A6 (see Appendix A) confirm the robustness of our findings.

Conclusion

This paper highlights the significant macroeconomic impacts of green public expenditure in Europe, showcasing its capacity to stimulate GDP growth, increase labour productivity, crowd-in private investment, and generate employment. Our results demonstrate that green public spending has larger fiscal multipliers compared to non-green alternatives, emphasizing its pivotal role in fostering sustainable economic recovery.

We find clear heterogeneity across Europe, with high-income countries exhibiting stronger GDP and employment effects, while low-income countries experience greater private investment and labour productivity responses. These findings highlight the need for green fiscal policies tailored to national contexts. In low-income countries, targeted green infrastructure investments can address innovation gaps, boost productivity, and reduce external dependence, while high-income countries should balance green spending and emphasize green consumption to foster growth and employment.

To accelerate the green transition amid the climate crisis, policymakers must optimize the composition of green public spending, balancing immediate benefits of green consumption with the long-term advantages of green investments. Tailored fiscal strategies are essential to maximize macroeconomic benefits and address structural disparities between low- and high-income European economies.

However, a limitation of our analysis is the high heterogeneity within the COFOG 05 aggregate, which groups distinct policy typologies under "environmental protection." Future research should further disaggregate green public spending to assess the specific effects of investment types—such as renewable energy, biodiversity protection, or pollution abatement—on macroeconomic outcomes. More broadly, progress on this front requires improved statistical infrastructure: harmonised, project-level tags for climate relevance across COFOG divisions (not only GF05), systematic green–brown splits within mixed programmes, and transaction-level reporting that preserves a transparent consumption–investment breakdown. Without such statistics, cross-country analyses face a trade-off between a conservative perimeter (GF05) and non-reproducible reclassification beyond it.

Building on these insights, we propose several directions for future research. First, leveraging quantile regression analysis can enhance understanding of differential responses across income distributions (Machado and Santos Silva, 2019). Second, exploring the complementarity between green investments and broader fiscal strategies can inform more effective policy design. Third, evaluating state-dependent effects, particularly during boom and slack periods, will shed light on the cyclical nature of green investment impacts (Ramey and Zubairy, 2018; Auerbach and Gorodnichenko, 2017). Future research could also explore the role of environmental regulation in shaping the macroeconomic effects of green public spending, particularly given the observed heterogeneity within Europe. For this purpose, the Environmental Policy Stringency Index could be employed to assess how varying levels of regulatory rigor influence the effectiveness of green expenditures across regions. Moreover a dedicated extension would embed our identification in a framework that captures cross-border propagation of fiscal shocks (for example, allowing for output spillovers across countries in the spirit of Auerbach and Gorodnichenko (2013). Lastly, further investigation into the debt sustainability implications of green public spending will be crucial in guiding long-term fiscal planning.

In conclusion, our analysis underscores the transformative potential of green public expenditure in addressing both economic and environmental challenges, reaffirming its importance as a cornerstone of sustainable development in Europe.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used large language models—OpenAI ChatGPT (GPT-5 Thinking and GPT-4o) and DeepSeek—solely to assist with writing-related tasks such as improving readability and grammar, clarifying phrasing, harmonising terminology, and resolving minor LaTeX formatting issues. These tools were used under human oversight; all suggestions were reviewed, edited, and, where necessary, substantially rewritten by the authors. No AI tools were used to analyse data, estimate models, or draw scientific conclusions. The authors take full responsibility for the content of the manuscript.

Appendix A

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
G^{tot}_{Green}							
Y	**1.92**	**2.47**	**3.03**	**3.14**	**3.61**	2.83	4.05
I_{priv}	**1.34**	**1.38**	**1.59**	**1.49**	0.95	1.35	1.95
λ_{tot}	**2.47**	**3.51**	4.06	4.69	**6.23**	4.19	6.41
φ_{labour}	**0.009**	**0.012**	**0.015**	**0.016**	**0.017**	0.014	0.022
G^{I}_{Green}							
Y	**1.79**	**1.80**	**2.08**	**2.19**	**2.97**	2.16	5.40
I_{priv}	0.41	0.54	0.73	0.71	**0.16**	0.51	1.01
λ_{tot}	0.69	0.52	0.19	0.10	**1.28**	0.56	5.50
φ_{labour}	**0.006**	**0.007**	**0.009**	**0.011**	**0.011**	0.009	0.014
G^{C}_{Green}							
Y	**2.21**	**3.42**	**4.60**	4.17	3.83	3.65	5.89
I_{priv}	3.33	3.53	**4.91**	**5.19**	**4.88**	4.37	6.50
λ_{tot}	**6.79**	**10.69**	**13.86**	**15.46**	**15.88**	12.54	17.14
φ_{labour}	**0.002**	**0.005**	**0.010**	**0.011**	**0.014**	0.008	0.018

Table A1: Robustness checks. Excluding 2020. Cumulative effects Green Public Expenditure (G^{tot}_{Green}, G^{I}_{Green}, G^{C}_{Green}). Significant estimates are in **bold** (68%).

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low income							
Y	**1.99**	**2.53**	**3.03**	3.03	2.74	2.67	3.73
I_{priv}	1.81	2.10	2.19	2.00	1.47	1.91	2.18
λ_{tot}	1.97	3.72	4.34	4.54	3.27	3.57	5.15
φ_{labour}	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	0.02	0.03
High income							
Y	**3.30**	**5.08**	**5.65**	5.71	5.25	5.00	7.00
I_{priv}	**0.49**	**0.15**	**0.41**	0.44	-0.29	0.24	-3.34
λ_{tot}	**3.28**	**4.50**	**5.51**	**6.67**	**7.42**	5.47	11.65
φ_{labour}	0.00	0.00	0.00	0.00	0.00	0.00	-0.01

Table A2: Robustness check: cumulative effects of Green Public Expenditure (G^{tot}_{Green}) using non-linear estimated shocks. Significant estimates are in **bold** (68%).

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low income							
Y	**1.33**	**1.35**	**1.81**	2.00	2.12	1.72	2.54
I_{priv}	0.75	0.78	0.93	0.92	0.79	0.84	1.13
λ_{tot}	0.42	0.08	-0.09	-0.75	-1.14	-0.30	-2.53
φ_{labour}	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	0.01	0.02
High income							
Y	**3.24**	**3.66**	3.83	**4.15**	3.64	3.71	4.27
I_{priv}	-0.13	-0.45	-0.14	-0.20	-0.65	-0.32	-2.10
λ_{tot}	**1.48**	2.13	2.01	**2.63**	**3.23**	2.30	4.73
φ_{labour}	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01

Table A3: Robustness check: cumulative effects of Green Public Investment (G^I_{Green}) using non-linear estimated shocks (high vs. low income countries). Significant estimates are in **bold** (68%).

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low income							
Y	**3.62**	**4.33**	**4.62**	**4.87**	**5.33**	4.55	4.69
I_{priv}	**4.50**	**4.53**	**5.25**	**5.89**	**6.00**	5.23	5.69
λ_{tot}	3.96	**7.17**	6.91	6.59	4.46	3.96	9.14
φ_{labour}	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	0.02	0.03
High income							
Y	2.44	**8.83**	**11.11**	10.94	11.16	8.90	15.50
I_{priv}	**4.58**	**5.39**	**7.95**	**8.79**	7.86	6.91	15.40
λ_{tot}	5.41	**8.65**	**12.76**	**14.64**	**15.24**	11.34	21.60
φ_{labour}	**-0.01**	0.00	0.00	**-0.01**	-0.01	-0.01	-0.02

Table A4: Robustness check: cumulative effects of Green Public Consumption (G^C_{Green}) using non-linear estimated shocks (high vs. low income countries). Significant estimates are in **bold** (68%).

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low level							
Y	**1.29**	**1.66**	1.59	1.54	1.44	1.51	1.80
I_{priv}	1.60	1.52	-0.04	**-1.41**	**-2.16**	-0.10	-4.73
λ_{tot}	0.90	1.44	2.06	2.83	3.20	2.08	4.50
φ_{labour}	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	0.01	0.02
High level							
Y	**1.50**	**1.44**	**2.46**	**3.10**	**3.60**	2.42	5.05
I_{priv}	1.16	1.36	**3.79**	**5.77**	**5.82**	3.58	11.34
λ_{tot}	**5.95**	5.89	5.32	5.21	4.38	5.35	5.94
φ_{labour}	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	0.01	0.02

Table A5: Robustness check: cumulative effects of Green Public Investment (G^I_{Green}) using non-linear estimated shocks (high vs. low share of green consumption). Significant estimates are in **bold** (68%).

	Year 0	Year 1	Year 2	Year 3	Year 4	Mean	Peak
Low level							
Y	2.64	4.01	5.24	4.32	3.12	3.87	6.16
I_{priv}	1.17	3.88	6.96	7.85	6.12	5.19	10.97
λ_{tot}	**11.81**	**17.68**	**22.58**	**27.74**	**30.43**	22.05	33.96
φ_{labour}	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01
High level							
Y	**3.42**	**4.34**	**4.19**	3.24	2.55	3.55	4.72
I_{priv}	**4.29**	3.36	**4.23**	**4.69**	4.32	4.18	5.58
λ_{tot}	**2.61**	**5.37**	6.86	6.21	4.43	5.09	8.93
φ_{labour}	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	0.01	0.03

Table A6: Robustness check: cumulative effects of Green Public Consumption (G^{C}_{Green}) using non-linear estimated shocks (high vs. low share of green consumption). Significant estimates are in **bold** (68%).

Appendix B

State-dependent difference tests

To test the statistical significance of state-dependent fiscal multipliers, we implement a direct instrumental-variable (IV) strategy in the spirit of Ramey and Zubairy (2018) adapted to a panel setting to allow for potential nonlinearities in the responses of our variables of interest (Y, I_{priv}, λ_{tot}, φ_{labour}) to green government spending shocks — total green expenditure (G^{tot}_{Green}), green public investment (G^{I}_{Green}), and green public consumption (G^{C}_{Green}) — across different economic regimes. We focus on two dimensions of nonlinearity.

Low- vs. high-income countries. First, we assess whether effects differ between countries classified as Low-Income (LI) and High-Income (HI). We estimate:

$$\begin{aligned}\sum_{h=0}^{H} \frac{y_{i,t+h} - y_{i,t-1}}{y_{i,t-1}} &= \beta^{h}_{1,LI} \sum_{h=0}^{H} \frac{G^{tot}_{\text{Green},\,i,t+h} - G^{tot}_{\text{Green},\,i,t-1}}{y_{i,t-1}} \cdot D^{LI}_{i} + \vartheta^{h}_{1,LI} x_{i,t-1} \cdot D^{LI}_{i} \\ &+ \beta^{h}_{2} \sum_{h=0}^{H} \frac{G^{tot}_{\text{Green},\,i,t+h} - G^{tot}_{\text{Green},\,i,t-1}}{y_{i,t-1}} + \vartheta^{h}_{2} x_{i,t-1} + \alpha_i + \delta_t + \varepsilon_{i,t+h},\end{aligned} \tag{B.1}$$

for $h = 0, \ldots, H$, where D^{LI}_{i} is a dummy equal to 1 if country i has GDP per capita below the sample median (and 0 otherwise). The cumulative green-spending terms $\sum_{h=0}^{H} \frac{G^{tot}_{\text{Green},\,i,t+h} - G^{tot}_{\text{Green},\,i,t-1}}{y_{i,t-1}} \cdot D^{LI}_{i}$ and $\sum_{h=0}^{H} \frac{G^{tot}_{\text{Green},\,i,t+h} - G^{tot}_{\text{Green},\,i,t-1}}{y_{i,t-1}}$ are instrumented with the (external) green spending shock interacted with D^{LI}_{i} and with the shock itself, respectively. In this setup, the coefficient β^{h}_{1} reads as the *difference in multipliers* between Low-Income (LI) and High-Income (HI) countries at horizon h.

Low vs. high share of green public consumption. Second, we examine whether effects differ between countries with a *low* versus *high* share of green public consumption relative to total green public expenditure. We estimate:

$$\sum_{h=0}^{H} \frac{y_{i,t+h} - y_{i,t-1}}{y_{i,t-1}} = \beta_{1,LS}^{h} \sum_{h=0}^{H} \frac{G^{tot}_{\text{Green},\,i,t+h} - G^{tot}_{\text{Green},\,i,t-1}}{y_{i,t-1}} \cdot D_{i,t}^{LS} + \vartheta_{1,LS}^{h} x_{i,t-1} \cdot D_{i,t}^{LS}$$
$$+ \beta_2^h \sum_{h=0}^{H} \frac{G^{tot}_{\text{Green},\,i,t+h} - G^{tot}_{\text{Green},\,i,t-1}}{y_{i,t-1}} + \vartheta_2^h x_{i,t-1} + \alpha_i + \delta_t + \varepsilon_{i,t+h}, \tag{B.2}$$

where $D_{i,t}^{LS}$ is a dummy equal to 1 if, in year t, the share $\frac{G^C_{\text{Green}}}{G^{tot}_{\text{Green}}}$ in country i is below the yearly sample median (0 otherwise). Here again, the cumulative green-spending terms interacted with $D_{i,t}^{LS}$ and the non-interacted ones are instrumented with the shock$\times D_{i,t}^{LS}$ and with the shock, respectively; in this case, $\beta_{1,LS}^{h}$ measures the *difference in multipliers* between low- and high-share countries.

The same models in (B.1)–(B.2) are estimated for G^I_{Green} (green public investment) and G^C_{Green} (green public consumption). Standard errors are computed using Driscoll and Kraay (1998).

	Year 0		Year 2		Year 4	
	difference	p-value	difference	p-value	difference	p-value
Y	-1.42	0.60	-2.49	0.38	**-3.48**	**0.27**
I_{priv}	**3.00**	**0.31**	**2.73**	**0.41**	**2.88**	**0.38**
λ_{tot}	-1.98	0.45	-2.80	0.42	**-5.41**	**0.28**
φ_{labour}	**0.02**	**0.10**	**0.03**	**0.00**	**0.04**	**0.00**

Table B1: Size and significance level of the differences between cumulative effects of Green Public Expenditure G^{tot}_{Green} (low income vs. high income). P-values based on Driscoll and Kraay (1998) standard errors.

	Year 0		Year 2		Year 4	
	difference	p-value	difference	p-value	difference	p-value
Y	-3.90	0.58	-0.35	0.99	0.39	0.99
I_{priv}	0.66	0.75	1.35	0.55	1.69	0.50
λ_{tot}	-1.11	0.62	-1.59	0.53	**-4.95**	**0.17**
φ_{labour}	0.01	0.58	**0.01**	**0.00**	**0.02**	**0.00**

Table B2: Size and significance level of the differences between cumulative effects of Green Public Investment G^I_{Green} (low income vs. high income). P-values based on Driscoll and Kraay (1998) standard errors.

	Year 0		Year 2		Year 4	
	difference	p-value	difference	p-value	difference	p-value
Y	-0.13	0.99	**-8.37**	**0.23**	**-9.75**	**0.24**
I_{priv}	-1.68	0.74	-4.18	0.55	-0.86	0.90
λ_{tot}	-0.72	0.88	-4.26	0.64	-5.92	0.52
φ_{labour}	**0.02**	**0.12**	**0.02**	**0.22**	**0.03**	**0.31**

Table B3: Size and significance level of the differences between cumulative effects of Green Public Consumption G^C_{Green} (low income vs. high income). P-values based on Driscoll and Kraay (1998) standard errors.

	Year 0		Year 2		Year 4	
	difference	p-value	difference	p-value	difference	p-value
Y	-0.42	0.75	-1.08	0.45	**-2.32**	**0.13**
I_{priv}	-2.15	0.83	**-14.73**	**0.07**	**-18.18**	**0.00**
λ_{tot}	**-3.08**	**0.17**	**-2.66**	**0.30**	-1.24	0.78
φ_{labour}	0.00	0.46	0.00	0.73	-0.01	0.69

Table B4: Size and significance level of the differences between cumulative effects of Green Public Investment G^I_{Green} (low vs. high share of green public consumption). P-values based on Driscoll and Kraay (1998) standard errors.

	Year 0		Year 2		Year 4	
	difference	p-value	difference	p-value	difference	p-value
Y	-2.73	0.50	-1.40	0.93	-2.07	0.77
I_{priv}	-2.08	0.53	1.26	0.90	1.12	0.93
λ_{tot}	**9.04**	**0.08**	**8.72**	**0.28**	13.56	0.33
φ_{labour}	**0.01**	**0.25**	0.00	0.62	0.01	0.36

Table B5: Size and significance level of the differences between cumulative effects of Green Public Consumption G^C_{Green} (low vs. high share of green public consumption). P-values based on Driscoll and Kraay (1998) standard errors.

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