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Research article

The effect of the Next Generation EU Funds on inequality: a DSGE model approach

María Malmierca-Ordoqui*, Carlos Arenas Laorga and Marta del Río Caballero

Social Sciences Department, Universidad Villanueva, Calle de la Costa Brava, 2. 28034 Madrid, Spain

* **Correspondence:** Email: maria.malmierca@villanueva.edu; Tel: +34 661118053

Abstract: The dire economic and social consequences of COVID-19 have led the European Commission to provide an unprecedented response to the pandemic crisis through the Next Generation EU program. In order to analyze the impacts of a variety of scenarios for the allocation of these funds, we developed a two-country New Keynesian model, representing the periphery and the core of the euro area. Based on asymmetric fiscal shocks, we show how European funds can bring sustainable economic growth and decrease consumption inequality in the recipient countries while causing negative spillovers in the countries not receiving the funds. The use of the recovery instrument to carry out productive public spending projects, or the reception of the funds in the form of grants, are factors that generate more permanent effects on inequality and growth in the beneficiary country.

Keywords: New Keynesian; Gini index; economic policy; euro area; NGEU

JEL Codes: D63, E12, E62, F45

1. Introduction

In 2020, Covid-19 was declared a public health emergency of international concern by the World Health Organization (WHO), as it disrupted the lives and well-being of millions of people worldwide. Beyond that, the pandemic dealt a severe blow to the global economy by negatively impacting production volumes, supply chains, and the financial system. In response to this crisis, the European Commission designed a recovery plan to provide economic support to the EU Member States through a massive and unprecedented fund called NextGenerationEU. This initiative is designed to foster a post-pandemic EU that is environmentally conscious, digitally advanced, resilient, and better equipped to confront current and future challenges. The centerpiece of NextGenerationEU is the Recovery and Resilience Facility (RRF), which provides grants and loans to support reforms and investments in EU Member States, totaling EUR 723.8 billion. Of these funds, EUR 338.0 billion will be provided as grants, while

EUR 385.8 billion will be available as loans on favorable terms to individual Member States, to be repaid by those States. The allocation of these funds will be based on national recovery and resilience plans developed by each Member State in collaboration with the European Commission, following an agreed allocation formula.

The pandemic has also led to a drastic increase in inequality within and between countries, as the most disadvantaged groups have been the hardest hit by the income losses caused by the crisis and are also the ones who need the most time to recover.

Our main objective of this analysis is to shed light on the effects that NextGeneration EU funds have on the EMU economy and sustainable development by comparing scenarios of fund distribution and usage in each of the two EMU regions (peripheral and core). The originality of the study is that we evaluate not only the economic effects of the European aid but also the social effects of the latter through the construction of a Gini index to observe the differences in consumption between affluent and more vulnerable households. In representing these households, we distinguish agents who save and borrow, thereby generating additional income beyond that from labor, and agents who do not have access to financial markets and consume their labor income entirely.

Our contribution is threefold. First, we analyze the reception of European funds based on exogenous fiscal shocks in the recipient country (Bozou and Creel, 2023). The introduced shocks are asymmetric so that both the national effects and the spillover effects can be isolated, considering the acquisition of funds by a peripheral country and by a core country. This enables us to evaluate how each region is affected by being a recipient of the aid and by the other region being the recipient.

Next, we distinguish two types of fiscal shocks to represent two alternative uses that each government can make of the received funds. On one hand, we consider the case where the funds are used to increase non-productive public spending. On the other hand, we analyze the case where the funds are allocated to public investment projects or productive government spending. We assess the impact that each of these uses has on the economic and social variables of both regions considered in the analysis.

Last, we provide recommendations on whether it is advisable to generate additional public debt in the countries receiving the aid from this recovery program. To do this, we compare the consequences of receiving these funds in the form of loans, which must be repaid by the Member States, with the consequences of receiving them in the form of grants, that do not increase the sovereign debt.

With this aim, we build a DSGE two-country model for a monetary union representing the peripheral and the core regions of the EMU. The periphery country is a net international borrower and the core country is a net international lender in line with Bordo (2014). Then, to characterize the external fiscal impulse to countries receiving the European funds, we follow Bozou and Creel (2023) and include asymmetric shocks either in the public non-productive spending rule or in the public investment rule.

Our results show that the NextGeneration EU funds might boost economic growth in the recipient region but might slow down economic activity in the other part of the EMU. Moreover, the European program might have an impact on social sustainability, concretely affecting households' inequality, that might vary depending on the country that receives the funds, the form in which they are distributed and the usage given to them.

The following graph presents the Gini index of the main economies in the Eurozone, together with the summary statistics. A clear distinction can be observed between countries categorized as peripheral (solid lines) and those belonging to the core of the union (dotted and dashed lines), with

the former exhibiting greater inequality than the latter. This evidence reinforces the motivation for our analysis, in which we examine European fiscal stimulus policies by comparing their effects on a country representing the periphery and another representing the core. Furthermore, an increase in inequality can also be observed in peripheral countries during the period 2007–2014, coinciding with years of public spending cuts in the Member States. This relationship is also reflected in our results.

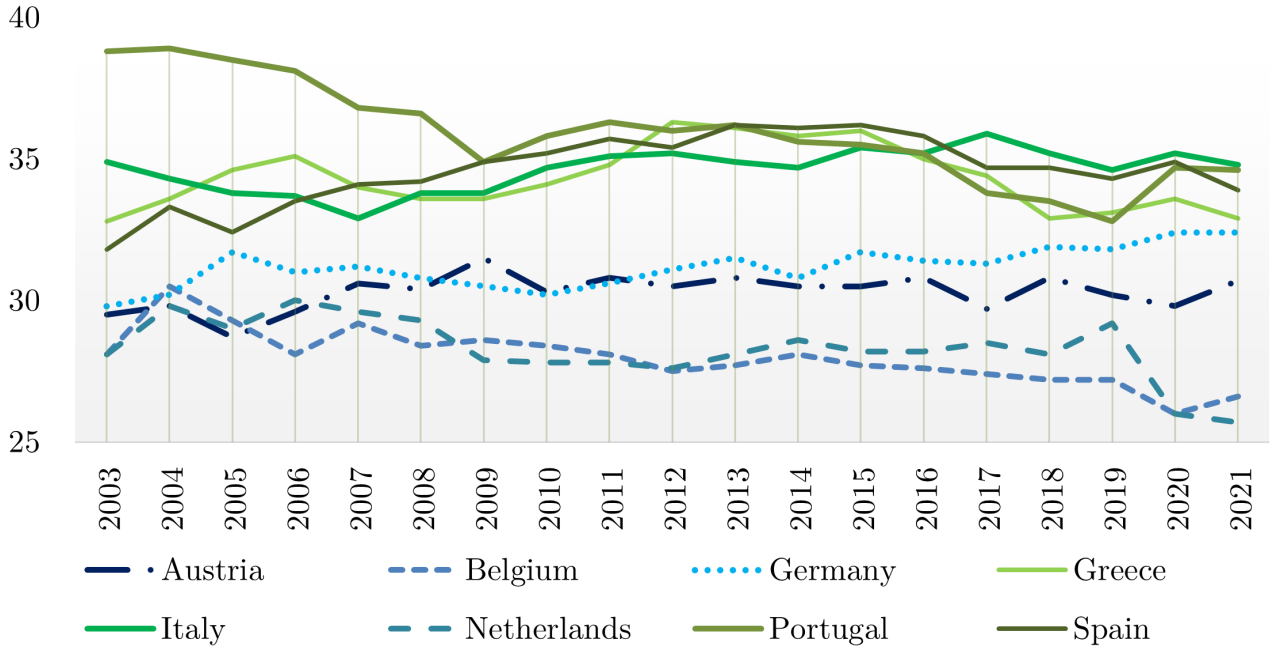

Figure 1. Gini index of periphery (solid lines) and core (dotted and dashed lines) countries of the Eurozone. Source: World Development Indicators Database. World Bank Databank.

The layout of the paper is as follows. In Section 2, we review the literature related to our study. In Section 3, we describe the two-country model developed to perform our study. In Section 4, we provide the model parametrization. In Section 5, we analyze the impulse response functions of a range of shocks representing different scenarios of reception and usage of the NGEU funds. In Section 6, we conclude the paper.

2. Related literature

In this article, we evaluate how the funds from the Next Generation EU program can influence the economic activity and social variables of the Eurozone Member States through the use of a DSGE model. Thus, this research first fits within the literature that develops new Keynesian models to analyze the role of economic policy in a monetary union. Christoffel et al. (2008) estimate the NAWM, a DSGE model for the Euro Area that provides a framework for the evaluation of economic policies and identification of the major sources of economic fluctuations. Ratto et al. (2009) present QUEST III, a DSGE model with fiscal and monetary policies to assess the influence of different policy combinations on economic stability. Quint and Rabanal (2014) show that the implementation of macroprudential policy can significantly improve economic stability and compensate for the lack of national monetary

Table 1. Summary statistics of the Gini index of countries of the Eurozone. World Bank Databank.

Gini Index	N	Mean	Standard deviation	Min	Max
Austria	19	30.29	0.64	28.70	31.50
Belgium	19	27.98	1.01	26.00	30.50
Germany	19	31.17	0.73	29.80	32.40
Greece	19	34.33	1.14	32.80	36.30
Ireland	19	32.05	1.27	29.20	33.80
Italy	19	34.64	0.74	32.90	35.90
Netherlands	19	28.29	1.12	25.70	30.00
Portugal	19	35.93	1.75	32.80	38.90
Spain	19	34.59	1.24	31.80	36.20

policy in the Eurozone. The interaction between monetary and fiscal policies has been the subject of much attention, especially regarding the transmission mechanisms in DSGE models. Benchimol et al. (2022) provide an interesting analysis of this policy interplay, highlighting the transmission channels of fiscal stimulus in a DSGE framework. Although they do not focus specifically on the euro area, their findings provide useful information on how coordinated monetary and fiscal interventions can mitigate adverse spillovers within a monetary union. More recently, other researchers who analyze the role of the policy mix in the Eurozone through microfounded DSGE models are Bartocci et al. (2020), Dehmej and Gambacorta (2017), Poutineau and Vermandel (2017), or Malmierca (2022,2023), among others.

A crucial aspect of our analysis is understanding how fiscal stimulus impacts inequality. Auclert, Rognlie and Straub (2024) provide valuable insights into the mechanisms through which fiscal policy affects inequality, emphasizing the role of heterogeneous agents and liquidity constraints. Their analysis highlights how fiscal stimulus can influence inequality by affecting household income distribution, employment, and wealth accumulation differently across constrained and unconstrained agents. Incorporating their framework clarifies the channels within our model by explicitly demonstrating how fiscal interventions shape consumption inequality through differential effects on constrained households.

Additionally, we expand our treatment of monetary-fiscal interactions, particularly relevant in the zero lower bound context experienced during COVID-19. Bianchi, Faccini, and Melosi (2020) extensively discuss monetary-fiscal coordination in a currency union subject to sovereign risk, emphasizing how active coordination can mitigate adverse economic outcomes when monetary policy is constrained by the zero lower bound. Their findings stress the importance of fiscal policy's role in stabilizing output and managing sovereign risks, providing a comprehensive understanding of policy coordination dynamics under such constraints, which significantly enriches our analysis

In addition, the distributional consequences of monetary policy and fiscal stimulus have gained prominence in the literature. Kaplan et al. (2018) present a Heterogeneous Agent New Keynesian (HANK) model that incorporates household heterogeneity to study how monetary policy affects the distribution of income and consumption. Unlike traditional representative agent models in DSGE, where households have full access to financial markets and can smooth consumption intertemporally, the

Kaplan et al. model introduces liquidity constraints and differences in access to credit, which generate differentiated responses to monetary shocks. Integrating such frameworks into the evaluation of NGEU funds provides a richer understanding of the social implications of the program.

Similarly, the two-agent New-Keynesian (TANK) methodology proposed by Debortoli and Galí (2024) captures the liquidity constraints faced by households and, by extension, the recipient countries of funds such as Next Generation EU (NGEU).

The identification of DSGE models is a very important aspect of validating their policy implications. Iskrev (2010) significantly contributes to this area by analyzing local identification issues in DSGE models, establishing criteria for determining parameter identifiability within these frameworks. Ivashchenko and Mutschler (2020) further examine the impact of observable variables, functional specifications, model features, and shock structures on the identification of parameters in linearized DSGE models, emphasizing the sensitivity of model identification to structural assumptions. Komunjer and Ng (2011) present a dynamic identification approach, demonstrating how time-series data and model structure contribute to identifying parameters and validating economic mechanisms within DSGE models. Moreover, Qu and Tkachenko (2012) propose a frequency domain quasi-maximum likelihood estimation methodology, offering improved techniques for parameter identification and estimation in linearized DSGE models, particularly relevant when dealing with complex dynamic interactions.

The treatment of financial frictions in DSGE models has evolved to include more sophisticated approaches. Gertler et al. (2020) develop a framework for analyzing financial panic mechanisms and their interactions with sovereign risk. Given the importance of financial stability in the context of the NGEU, the incorporation of bank-sovereign feedback loops provides additional information on the long-term effectiveness of European recovery programs. Similarly, the response of the corporate sector to NGEU stimulus can be assessed through the lens of Brunnermeier and Krishnamurthy (2020), who explore corporate balance sheet constraints and their implications for macroeconomic stability.

From a computational perspective, Auclert et al. (2021) propose a Jacobian sequence-space method that enables more efficient solutions in heterogeneous agent frameworks. The incorporation of these numerical techniques could improve the tractability of DSGE models, especially when assessing the broad spillover effects of fiscal interventions.

There is also an extensive literature considering the importance of DSGE models in the evaluation of economic policy in times of Covid-19. Born and Pfeifer (2021) offer an approach to model the dynamics of markups under nominal rigidities, especially relevant in light of supply shocks following the COVID-19 pandemic. Moreover, Forbes (2021), Bergant and Forbes (2021), Edwards (2021), Igan et al. (2022) analyze the macroprudential policy implementation after the pandemic shock. More specifically, our work is closely related to those articles focused on the response of authorities to the Covid-19 crisis in the European Monetary Union (EMU). Bartocci et al. (2020) analyze the monetary-fiscal interaction in a DSGE model for a monetary union affected by a pandemic. Malmierca-Ordoqui (2024) analyzes the stabilization properties of the fiscal-macroprudential policy cooperation after a pandemic shock and after a financial shock.

There are some researchers that have analyzed the NGEU program implementation, emphasizing the potential of these funds to promote an equitable and sustained recovery in the Eurozone. For instance, Picek (2020) highlights the importance of fiscal policy coordination across the European Union to ensure that the reconstruction objectives of the NGEU program are met and Schramm et al. (2022) analyze the impact that the RRF plan is likely to have on European cohesion.

The literature using the DSGE methodology to analyze the effects of the NGEU is very scarce. Pfeiffer et al. (2021) quantify the spillover effects of a coordinated investment stimulus in the EU, providing evidence on the benefits of public investments beyond national borders. Although our results differ by focusing our analysis on only two regions, we agree with them in emphasizing the potential of NGEU funds to generate effects beyond the direct recipient countries. Boscá et al. (2021) evaluate the stabilizing effects of economic policies in Spain during the COVID-19 pandemic, highlighting the importance of effective implementation of fiscal and monetary policies in times of crisis. Bańkowski et al. (2021), through a micro-founded multi-country DSGE model, assess how different uses of the NGEU instrument affect the Euro Area macroeconomy. We also focus our analysis on two applications of the NGEU, non-productive public spending and productive public spending, but our analysis is based on a two-country model to show the periphery and core characteristics. This simplified representation of the monetary union is widely adopted in the literature, as it allows isolating and clearly reflecting the effects of shocks, ensuring they are not obscured by an excessively complex model. Bozou and Creel (2023) also compare the macroeconomic effects of the European recovery plan NGEU with national plans. In line with them, we model the reception of NGEU funds as exogenous fiscal shocks that hit either the periphery or the core, according to what country receives the European aid.

However, to the best of our knowledge, we are the first to explore the effects of NGEU funds on inequality through a DSGE model. We focus on comparing different scenarios of distributing these European aids in terms of their impact on inequality, measured by the Gini index and based on Areosa and Areosa (2016). The latter introduce this variable to a DSGE model to examine optimal monetary policy.

The effects of economic policy on inequality is very prominent in the literature. McKay and Wolf (2023) explore the links between monetary policy an inequality and find that the transmission channel propagates differently when accounting for households heterogeneity. Andersen et al. (2023) implement an empirical analysis to show that increases in the interest rate might reduce households inequality. Mian, Straub and Sufi (2022) conduct an analysis, somewhat parallel to ours, by showing a connection between government debt and household inequality. In their case, they find that greater inequality increases fiscal space; in our case, we aim to observe the effect of the public sector on that inequality. Ravenna and Vincent (2014) build a DSGE model with heterogeneous agents to assess the relationship between inequality and debt, providing a perspective on the factors that are key for debt to income divergence across households. Menna and Tirelli (2017) also develop a DSGE model that leads them to conclude that high inflation, accompanied by a reduction in the income tax rate, can result in a decrease in inequality. Eskelinen (2021) demonstrates in an heterogeneous agent New Keynesian model that the transmission of monetary policy occurs through a redistribution channel that affects inequality. The outcomes obtained in the mentioned papers robust the results of our analysis, performed with the aim of delving deeper into the effects on inequality by examining the impact of another unprecedented economic policy, the NGEU program.

3. The model

Our DSGE model consists of a two-country monetary union representing the two regions of the EMU: The periphery and the core. To measure the inequality effects of the NGEU funds, we differentiate between households that have access to saving and borrowing and households that do not have access to the financial markets. The rest of agents of each economy are intermediate good producers and

final good producers, entrepreneurs, capital goods producers, and domestic financial intermediaries. There are also international financial intermediaries to connect the domestic financial intermediaries of both countries. Fiscal authorities are national. We also consider financial frictions modeled as in Bernanke et al. (1999), an incomplete financial market (Quint and Rabanal, 2014), and an international goods market. We assume that capital and labor are non-mobile across countries. Both countries are of equal size. Below, we present only the periphery country block of the model. The core country is characterized by a similar structure, unless specified. In what follows, variables and parameters of the core country are denoted with superscript $*$.

3.1. Households

There is a continuum of households with infinite life. A fraction $1 - \omega^{NR}$ of these agents have access to financial markets and can borrow and save. We refer to them as *Ricardian* households. The remaining fraction ω^{NR} of households are excluded from the financial markets and just consume all their income. We use the term *non-Ricardian* households to refer to that subset of consumers.

3.1.1. Ricardian consumers

Ricardian households consume, work, and save. These agents maximize a utility function, choosing total consumption, c_t^R, labor, l_t^R, and financial assets in the form of either deposits, a_t, or public debt, d_t. The utility function is given by

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\log\left(c_t^R\right) - \psi^R \frac{l_t^{R(1+\vartheta)}}{1+\vartheta} \right], \tag{1}$$

and $\beta \in (0,1)$ is the discount factor; the labor disutility is represented by $\psi > 0$; and $\vartheta > 0$ denotes the inverse of the Frisch elasticity of labor.

These households make decisions subject to the budget constraint:

$$(1+\tau_c)\, c_t^R + \frac{a_t}{p_t} + \frac{d_t}{p_t} = (1-\tau_l)\, w_t l_t^R + \left[1 + (1-\tau_R)\left(R_{t-1} - 1\right)\right] \frac{a_{t-1}}{p_t} + R_{t-1}^d \frac{d_{t-1}}{p_t} + F_t + tre_t. \tag{2}$$

The Ricardian households' expenditures are represented in the left hand side of equation (2) and the Ricardian households' income appear in the right hand side. These sources of income are: Labor income, w_t being real wage; interests on last period deposits, $R_{t-1}a_{t-1}$ and on public debt, $R_{t-1}^d d_{t-1}$; and net transfers from the government, T_t. Households pay proportional taxes on consumption, τ_c, on labor income, τ_l and on deposits returns, τ_R. Firms pay dividends to households, F_t; and tre_t is a net transfer from entrepreneurs:

$$tre_t = (1-\gamma^e)\, n_t - w^e, \tag{3}$$

where $\gamma^e = \frac{1}{1+e^{-\bar{\gamma}^e}}$ is the rate of entrepreneurs that survives from one period to the next one. Thus the net wealth of the dead entrepreneurs, $(1-\gamma^e)\, n_t$, is received by households who transfer w^e to incoming entrepreneurs.

3.1.2. Non-Ricardian consumers

These agents do not borrow or save as we assume that they do not have access to financial markets. As a result, they cannot smooth consumption, c_t^{NR}, and they spend all of their labor income, $w_t l_t^R$. Their utility function is given by

$$\log\left(c_t^{NR}\right) - \psi^{NR}\frac{l_t^{NR(1+\vartheta)}}{1+\vartheta}, \tag{4}$$

and their budget constraint is denoted by:

$$(1+\tau_c)\, c_t^{NR} = (1-\tau_l)\, w_t l^N R_t. \tag{5}$$

As this was the case for Ricardian consumers, the left hand side of equation (5) represents the non-Ricardian household's expenditures, and the right hand side the labor income, $w_t l_t^{NR}$, that is, their only source of income.

3.1.3. Gini index

We define the consumption of the ω^{NR} non-Ricardian consumers as $\eta_t c_t$, while the $1-\omega^{NR}$ Ricardian consumers consume the remaining $(1-\eta_t)c_t$. We normalize c_t to unity and assume that $c_t^{NR} < c_t^R$. Based on Areosa and Areosa (2016), we construct Gini index for consumption, gi_t, that measures inequality, and is given by,

$$gi_t = \omega^{NR} - \eta_t. \tag{6}$$

The share of total consumption by non-Ricardian consumers, η_t, is the equal to:

$$\eta_t = \frac{\omega^{NR} c_t^{NR}}{c_t}. \tag{7}$$

3.1.4. International goods market

To choose their allocations between periphery and core country goods, all households maximize the consumption index, which follows:

$$c_t = \left[(1-\varphi)^{\frac{1}{\zeta}}\left(c_{P,t}\right)^{\frac{\zeta-1}{\zeta}} + \varphi^{\frac{1}{\zeta}}\left(c_{C,t}\right)^{\frac{\zeta-1}{\zeta}}\right]^{\frac{\zeta}{\zeta-1}}, \tag{8}$$

subject to total consumption expenditures,

$$p_t c_t = p_{P,t} c_{P,t} + p_{C,t} c_{C,t}, \tag{9}$$

where $c_{P,t}$ is the consumption of domestic goods by periphery consumers, and $c_{C,t}$ is the consumption of core country goods by the periphery consumers, i.e, the amount of imports by the periphery. Parameter $\varphi \in [0,1]$ represents the degree of openness and parameter $\zeta > 0$ the degree of substitutability between periphery country goods and core country goods. The price of periphery country goods, $p_{P,t}$, and the price of core country goods, $p_{C,t}$ compose the periphery consumer price index, p_t. For simplicity, we assume that the law of one price holds, i.e, the prices of goods produced and sold are the same across countries. The demand for $c_{P,t}$ and $c_{C,t}$ are derived from this maximization problem.

Finally, the variable terms of trade, t_t, expresses the price in the core relative to that in the periphery, representing the degree of competitiveness, and is given by

$$t_t = \frac{p_{C,t}}{p_{P,t}}. \tag{10}$$

3.2. Intermediate goods producers

Intermediate goods producers sell differentiated goods in a monopolistically competitive market to final good producers. They follow the production function:

$$y_{it} = e^{z_t} k_{it-1}^{\alpha} l_{it}^{1-\alpha} k_{g,t-1}^{\alpha_g}, \tag{11}$$

where labor, l_t, private capital, k_{t-1}, and public capital, $k_{g,t-1}$, are factors of production to create output, y_t, $0 \leq \alpha \leq 1$ is the share of private capital in the production function and $0 \leq \alpha_g \leq 1$ is the elasticity of output to public capital.

Technology follows an exogenous AR(1) process $z_t = \rho_z z_{t-1} + \sigma_z \varepsilon_{z,t}$ where $0 < \rho_z < 1$ and $\varepsilon_{z,t} \backsim N(0,1)$. Parameter ρ_z is the persistence coefficient and parameter σ_z the shock volatility.

Intermediate goods producers minimize their costs function subject to their production function. They hire labor from households and they pay them the real wage, w_t. These firms also rent capital from entrepreneurs and they pay them the real interest rate, r_t.

Intermediate firms reset their prices following a Calvo pricing mechanism by which each period, a fraction $1-\theta$ of firms, can change their price, while the rest, θ, keep the previous period's price, indexed to past inflation.

The fraction of intermediate firms resetting their price in period t maximizes their discounted profits,

$$E_t \sum_{\tau=0}^{\infty} (\beta\theta)^{\tau} \frac{\lambda_{t+\tau}}{\lambda_t} \left[\left(\prod_{s=1}^{\tau} \frac{\Pi_{P,t+s-1}^{\chi}}{\Pi_{P,t+s}} \frac{p_{P,it}}{p_{P,t}} - mc_{t+\tau} \right) y_{it+\tau} \right], \tag{12}$$

subject to a sequence of demand functions*

$$y_{it+\tau} = \left(\prod_{s=1}^{\tau} \frac{\Pi_{P,t+s-1}^{\chi}}{\Pi_{P,t+s}} \frac{p_{P,it}}{p_{P,t}} \right)^{-\varepsilon} y_{t+\tau}. \tag{13}$$

In the expressions above, $\frac{\lambda_{t+\tau}}{\lambda_t}$ is the stochastic discount factor, taken as given by the intermediate good producer; mc_t denotes the marginal cost; $p_{P,it}$ is the price set in period t by the intermediate goods producer i; $p_{P,t}$ is the aggregate domestic price level; $\Pi_{P,t}$ denotes domestic inflation; $y_{it+\tau}$ represents output at $t+\tau$ for firms that last reset their price in period t; $y_{t+\tau}$ is the aggregate output in time $t+\tau$, and $\varepsilon \geq 1$ is the value of the substitution elasticity across goods. The domestic reset price relative to the domestic price level is $\bar{\Pi}_{P,t} = \frac{\bar{p}_{P,t}}{p_{P,t}}$.

The aggregate price index follows:

$$1 = \theta \left(\frac{\Pi_{P,t-1}^{\chi}}{\Pi_{P,t}} \right)^{1-\varepsilon} + (1-\theta)\, \bar{\Pi}_{P,t}^{(1-\varepsilon)}. \tag{14}$$

*The individual demand for each differentiated good is in line with the Dixit and Stiglitz (1977) specification.

3.3. Final goods producers

These agents buy intermediate goods and use them to produce the homogeneous final good according through the following Dixit-Stiglitz function:

$$y_t = \left(\int_0^1 y_{it}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{15}$$

where y_t is the aggregate demand of the economy, and $\varepsilon > 1$ is the elasticity of substitution across goods. Final goods producers sell the final goods in a perfectly competitive market. Thus, they maximize profits, taking the price of the intermediate good $p_{P,it}$ and the price of the final good $p_{P,t}$. The domestic price level is

$$p_{P,t} = \left(\int_0^1 p_{P,it}^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}. \tag{16}$$

3.4. Capital goods producers

Capital producers also operate in a perfectly competitive market by creating new capital, x_{t+1}, through the use of investment, i_t, and installed capital, x_t, combined in the following production function:

$$x_{t+1} = x_t + \left(1 - S\left[\frac{i_t}{i_{t-1}} \right] \right) i_t, \tag{17}$$

where $S\left[\frac{i_t}{i_{t-1}}\right]$ accounts for adjustment costs, such that $S'[\cdot] > 0; S''[\cdot] > 0; S[1] = 0$; and $S'[1] = 0$. They purchase installed capital from entrepreneurs. With q_t denoting the relative price of capital, discounted profits are expressed as

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[q_t \left(1 - S\left[\frac{i_t}{i_{t-1}} \right] \right) i_t - i_t \right]. \tag{18}$$

The law of motion of capital is given by

$$k_t = (1-\delta) k_{t-1} + \left(1 - S\left[\frac{i_t}{i_{t-1}} \right] \right) i_t, \tag{19}$$

where $\delta \in [0, 1]$ is the capital depreciation rate.

3.5. Entrepreneurs

Entrepreneurs use installed capital, x_t, to transform it into final capital rented by intermediate goods producers, k_{t-1}. Each period, entrepreneurs use internal and external funds to buy new capital, k_t, created by capital goods producers, at price q_t, so that they can undertake their investment project. Internal funds consists of end-of-period entrepreneurs' net worth , n_t and external funds are private debt in the form of loans borrowed from domestic financial intermediaries, b_t. Therefore, real private debt is given by:

$$\frac{b_t}{p_t} = q_t k_t \frac{p_{P,t}}{p_t} - n_t. \tag{20}$$

Their technology is affected by an idiosyncratic shock, ω_{t+1}, lognormally distributed with cumulative distribution $F(\omega, \sigma_{\omega,t})$ with parameters $\mu_{\omega,t}$ and $\sigma_{\omega,t}$. We assume that $E_t\omega_{t+1} = 1$ for all t. The dispersion, $\sigma_{\omega,t}$, is the credit risk of the model that may arise from household overborrowing or from risk-taking in financial markets and follows:

$$\frac{\sigma_{\omega,t}}{\sigma_\omega} = \left(\frac{\sigma_{\omega,t-1}}{\sigma_\omega}\right)^{\rho_{\sigma_\omega}} \exp\left(\eta_{\sigma_\omega}\varepsilon_{\sigma_\omega,t}\right) \text{ where } \varepsilon_{\sigma_\omega,t} \backsim N(0,1). \tag{21}$$

Parameter $\rho_{\sigma_\omega} \in [0,1]$ is the persistence coefficient and parameter η_{σ_ω} is the volatility of the shock, which is revealed just before the investment decisions for $t+1$ are taken, that is, at the end of the period.

Entrepreneurs charge a price,r_{t+1}, per unit of capital rented to intermediate good producers and a price, $q_{t+1}(1-\delta)$, for the repurchase of the old capital to capital good producers, at the end of the period. Then the entrepreneurs' ex-post average return per unit of investment, R^k_{t+1}, is equal to

$$R^k_{t+1} = \Pi_{P,t+1}\frac{r_{t+1} + q_{t+1}(1-\delta)}{q_t}. \tag{22}$$

The realization of ω_{t+1} is private information to entrepreneurs, and the contract with domestic financial intermediaries is signed before it is known. The financial sector faces a costly state verification problem as, in line with Bernanke et al. (1999), entrepreneurs do not pay for the observation of their outcome, while domestic financial intermediaries have to pay for this information. The cost paid by domestic financial intermediaries is proportional to the gross payoff of the entrepreneur's capital.

To solve this problem, domestic financial intermediaries and entrepreneurs, through a standard debt contract, set a state-contingent non-default repayment, R^l_{t+1}, dependent on R^k_{t+1}, that entrepreneurs will pay to domestic financial intermediaries if they succeed in their investment project. Otherwise, the entrepreneur will default.

At the moment of the lending agreement, R^k_{t+1} is not known and, therefore, there is aggregate uncertainty. When entrepreneurs decide the amount of external funds they need, they agree with the domestic financial intermediaries the one period contract. There is a threshold value of the idiosyncratic shock, ϖ_{t+1}, below which the entrepreneur defaults, and is given by

$$R^l_{t+1}b_t = \varpi_{t+1}R^k_{t+1}p_{P,t}q_tk_t. \tag{23}$$

Hence, the costly state verification problem ensures that whenever the return of the investment project is enough to pay the entrepreneurs' obligations, the latter have an incentive to do so (Freixas and Rochet, 2008).

The interest rate that domestic financial intermediaries get form entrepreneurs, R^l_{t+1}, is also established in the lending agreement, and it arises from the former's zero profit condition:

$$\left[1 - F(\varpi_{t+1}, \sigma_{\omega,t})\right]R^l_{t+1}b_t + (1-\mu)\int_0^{\varpi_{t+1}} \omega dF(\omega, \sigma_{\omega,t})R^k_{t+1}p_{P,t}q_tk_t = R_t(a_t + B_t). \tag{24}$$

In the preceding equation, a_t represents national funds while B_t denotes those originating from the international financial market. Entrepreneurs then choose the leverage ratio and the schedule for ϖ_{t+1} by maximizing their expected net worth (Fernández-Villaverde, 2010a),

$$\max_{\frac{b_t}{\frac{p_t}{n_t}}, \varpi_{t+1}} \frac{R^k_{t+1}}{R_t}\left[1 - \Gamma(\varpi_{t+1}, \sigma_{\omega,t})\right]\left(1 + \frac{\frac{b_t}{p_t}}{n_t}\right), \tag{25}$$

subject to domestic financial intermediaries' zero profit condition,

$$\left[\frac{R_{t+1}^{k}}{R_t}\left[\Gamma\left(\varpi_{t+1},\sigma_{\omega,t}\right)-\mu G\left(\varpi_{t+1},\sigma_{\omega,t}\right)\right]\left(1+\frac{\frac{a_t+B_t}{p_t}}{n_t}\right)-\frac{\frac{a_t+B_t}{p_t}}{n_t}\right], \tag{26}$$

and given that in equilibrium $a_t + B_t = b_t$. The probability of default is denoted by $F\left(\varpi_{t+1},\sigma_{\omega,t}\right)$ and then

$$G\left(\varpi_{t+1},\sigma_{\omega,t}\right)=\int_{0}^{\varpi_{t+1}}\omega dF\left(\omega,\sigma_{\omega,t}\right). \tag{27}$$

The share of entrepreneurial earnings accrued to domestic financial intermediaries is expressed by

$$\Gamma\left(\varpi_{t+1},\sigma_{\omega,t}\right)=\varpi_{t+1}\left[1-F\left(\varpi_{t+1},\sigma_{\omega,t}\right)\right]+G\left(\varpi_{t+1},\sigma_{\omega,t}\right). \tag{28}$$

At the end of every period, a fraction γ^e of entrepreneurs survives while the rest die. The new entrepreneurs replacing the dead ones receive an initial net worth w^e from households.

The average net wealth follows

$$n_t=\gamma^e\frac{1}{\Pi_t}\left\{\left[1-\mu G\left(\varpi_t,\sigma_{\omega,t-1}\right)\right]R_t^k q_{t-1}k_{t-1}\frac{p_{P,t-1}}{p_{t-1}}-R_{t-1}\frac{b_{t-1}}{p_{t-1}}\right\}+w^e. \tag{29}$$

3.6. Domestic financial intermediaries

In a perfectly competitive market, these agents receive deposits from households, a_t, and lend loans to entrepreneurs, b_t. Domestic financial intermediaries obtain foreign funds from the international financial market when the amount of loans that entrepreneurs wish to borrow exceeds the quantity of household deposits and lend those international funds, $B_t > 0$, to entrepreneurs. Domestic financial intermediaries also deposit the excess of domestic funds in the international financial markets when the number of domestic deposits exceed the amount of loans borrowed, $B_t < 0$.

The domestic financial intermediaries' objective function is given by

$$\left\{\left[1-F\left(\varpi_{t+1},\sigma_{\omega,t}\right)\right]R_{t+1}^{l}b_t+\left(1-\mu\right)\int_{0}^{\varpi_{t+1}}\omega dF\left(\omega,\sigma_{\omega,t}\right)R_{t+1}^{k}p_{P,t}q_t k_t-R_t\left(a_t+B_t\right)\right\}, \tag{30}$$

which shows expected returns in case entrepreneurs succeed, plus revenues in case the latter default, minus the costs for the financial intermediary. This objective function will be equal to zero according to equation (24).

3.7. International financial intermediaries

There are international financial intermediaries that connect domestic financial intermediaries of both countries (as in Quint and Rabanal, 2014). They take funds from the country with deposit surplus to lend to the other country, with shortage of loanable funds. International financial intermediaries pay to the lending country the interest rate on deposits of that country and receive, from the borrowing country, the interest rate on deposits of that other country. The profit of international financial intermediaries is the differential between the deposit rates of both countries because markets are incomplete. This interest rate differential is the country debt premium, given by[†]

$$R_t-R_t^*=e^{\Omega\left(\frac{B_t}{p_t y}-\frac{B}{py}\right)}-1. \tag{31}$$

[†]Given our model and calibration, the zero lower bound is not binding, and interest rates, as well as their differences, will always take values above zero, thereby preventing stationarity issues.

We introduce an interest rate that is increasing in the level of debt to induce stationarity in line with Schmitt-Grohé and Uribe (2003). The debt premium depends on the ratio of real international debt, $\frac{B_t}{p_t}$, to steady state real GDP, y, of the peripheral country because, for simplicity, we take that country as the reference. Real international debt is denoted by $\bar{B}_t$ and real private debt by $\bar{b}_t$. If the peripheral country borrows, then $B_t > 0$ and $R_t > R_t^*$. If the peripheral country lends, then $B_t < 0$ and $R_t < R_t^*$. Parameter $\Omega > 0$ is the elasticity of the debt premium.

3.8. Fiscal authority

The national government uses taxes and public debt to finance its expenditures, according to a budget constraint:

$$\frac{d_t}{p_t} = g_t + i_{g,t} + R_{t-1}^d \frac{d_{t-1}}{p_t} - tax_t, \tag{32}$$

where d_t denotes a current issue of public debt; g_t is non-productive government spending; and $i_{g,t}$ is productive government spending or public investment. Tax revenues, tax_t, are defined by

$$tax_t = \tau_c c_t + \tau_l w_t l_t + \tau_R \left(R_{t-1} - 1\right) \frac{a_{t-1}}{p_t}. \tag{33}$$

To model the NextGeneration EU funds reception and use, we introduce two fiscal rules to the model and consider the possibility of fiscal shocks affecting both rules (this is in line with Bozou and Creel, 2023). Therefore, the non-productive government spending follows

$$\frac{g_t}{g} = \left(\frac{g_{t-1}}{g}\right)^{\gamma_g} \exp\left(d_g \frac{d_{t-1}}{\Pi_t y_t} - \frac{d}{\Pi y}\right) \exp\left(\sigma_g \varepsilon_{g,t}\right), \text{ where } \varepsilon_{g,t} \backsim N(0,1). \tag{34}$$

Parameter $d_g \leq 0$ is the sensitivity of non-productive government expenditure to changes in the ratio of debt over output; $\gamma_g \in [0,1]$ is the persistence coefficient; and σ_g is the volatility of the government spending shock.

Also, public investment evolves by the following rule:

$$\frac{i_{g,t}}{i_g} = \left(\frac{i_{g,t-1}}{i_g}\right)^{\gamma_{ig}} \exp\left(d_{ig} \frac{d_{t-1}}{\Pi_t y_t} - \frac{d}{\Pi y}\right) \exp\left(\sigma_{ig} \varepsilon_{ig,t}\right), \text{ where } \varepsilon_{ig,t} \backsim N(0,1). \tag{35}$$

In this case, parameter $d_{ig} \leq 0$ is the sensitivity of public investment to changes in the ratio of public debt-to-GDP; $\gamma_{ig} \in [0,1]$ is the persistence coefficient; and σ_{ig} is the volatility of the government spending shock.

In the two previous equations, the steady states of the corresponding variables are indicated without the subscript t (d, y, Π, g, i_g).

Furthermore, the government produces public capital, which is used in the intermediate production function, is depreciated at rate δ_g, and follows the law of motion

$$k_{g,t} = \left(1 - \delta_g\right) k_{g,t-1} + i_{g,t}. \tag{36}$$

3.9. Monetary authority

The monetary authority is common for both countries and follows a conventional Taylor rule. This analysis implements an active monetary policy according to Leeper (1991) so that the policy rate is unconstrained by the government budget and stabilizes aggregate inflation, Π_t^{MU}, and real aggregate output, y_t^{MU} .

The monetary union inflation is equal to:

$$\Pi_t^{MU} = \frac{p_t^{MU}}{p_{t-1}^{MU}}, \tag{37}$$

where

$$p_t^{MU} = (p_t)^n \left(p_t^*\right)^{1-n}, \tag{38}$$

and the monetary union real output is

$$y_t^{MU} = (y_t)^n \left(y_t^*\right)^{1-n}. \tag{39}$$

The Taylor Rule followed by the Central Bank is given by:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left(\left(\frac{\Pi_t^{MU}}{\Pi^{MU}}\right)^{\gamma_\Pi}\right)^{(1-\gamma_R)} \exp(\sigma_m \varepsilon_{m,t}), \tag{40}$$

where $\gamma_R \in [0, 1]$ is the persistence parameter; $\gamma_\Pi \geq 0$ and $\gamma_y \geq 0$ indicate how strong the response of the interest policy rate to deviations of Π_t^{MU} and y_t^{MU} is from their steady states, respectively; and σ_m is the volatility of the monetary policy shock, $\varepsilon_{m,t} \backsim N(0, 1)$.

The nominal interest rate is modified through open market operations financed by transfers to households, T_t and T_t^* for the peripheral and core country, respectively.

3.10. Equilibrium and market clearing

The equilibrium in this model implies that optimality conditions are satisfied for all agents of both countries in the model; and that all markets clear, that is, in the case of the periphery country, aggregate demand is,

$$y_t = c_{P,t} + \frac{1-n}{n} c_{P,t}^* + i_t + g_t + i_{g,t} + \mu G\left(\varpi_t, \sigma_{\omega,t-1}\right)\left(r_t + q_t\left(1-\delta\right)\right) k_{t-1}, \tag{41}$$

and aggregate supply is,

$$y_t = \frac{1}{\upsilon_t} e^{z_t} k_{t-1}^{\alpha} l_t^{1-\alpha} k_{g,t-1}^{\alpha_g}, \tag{42}$$

being υ_t the inefficiency created by price dispersion that follows:

$$\upsilon_t = \theta\left(\frac{\Pi_{P,t-1}^{\chi}}{\Pi_{P,t}}\right)^{-\varepsilon} \upsilon_{t-1} + (1-\theta)\left(\bar{\Pi}_{P,t}\right)^{-\varepsilon}. \tag{43}$$

The labor market clearing is implied by

$$l_t^s = l_t^d, \tag{44}$$

and the international and domestic financial markets'equilibrium, respectively, are represented by:

$$nB_t = (1-n)\left(-B_t^*\right) \tag{45}$$

$$a_t + B_t = b_t. \tag{46}$$

The aggregation equations are

$$c_t = \left(1-\omega^{NR}\right) c_t^R + \omega^{NR} c_t^{NR}, \text{and} \tag{47}$$

$$l_t = \left(1-\omega^{NR}\right) l_t^R + \omega^{NR} l_t^{NR} \tag{48}$$

and the periphery country's net foreign asset position is

$$n\bar{B}_t = nR_{t-1}\frac{\bar{B}_{t-1}}{\Pi_t} + n\frac{p_{C,t}}{p_t}c_{C,t} - (1-n)\frac{p_{P,t}}{p_t}c_{P,t}^*. \tag{49}$$

For the core country, the market clearing and aggregations are replicated using core country variables.

4. Calibration of the parameters and steady state

Table 2 reports the model calibration. Most of the parameters are based on Quint and Rabanal (2014), Fernández-Villaverde (2010b, 2012), or Bozou and Creel (2023). For all the autorregressive processes, persistence takes the value 0.95, a conventional choice in the literature. To make NGEU shocks comparable, we use a public investment shock volatility equal to four times the public spending shock volatility.

Table 2. Calibration and steady state.

Parameter	Description	Value	Source
β	Discount factor	0.99	Quint and Rabanal (2014)
$\frac{c_C}{y}$	Imports-to-GDP	0.06	Quint and Rabanal (2014)
$\frac{c_P^*}{y^*}$	Exports-to-GDP	0.09	Quint and Rabanal (2014)
ζ	Substitutability between domestic and foreign goods	1.5	Quint and Rabanal (2014)
Ω	Debt elasticity of country premium	0.0043	Quint and Rabanal (2014)
ϑ	Inverse of Frisch elasticity of labor	0.5	Fernández-Villaverde (2012)
α	Capital share	0.33	Fernández-Villaverde (2012)
δ	Capital depreciation rate	0.023	Fernández-Villaverde (2012)
α_{ig}	Elasticity of output to public capital	0.1	Bozou and Creel (2023)
δ_{ig}	Public capital depreciation rate	0.0125	Bozou and Creel (2023)
θ	Periphery country calvo parameter	0.72	Quint and Rabanal (2014)
θ^*	Core country calvo parameter	0.62	Quint and Rabanal (2014)
ε	Elasticity of substitution between intermediate goods	8.577	Fernández-Villaverde (2012)

Parameter	Description	Value	Source
χ	Degree of indexation	0.6	Fernández-Villaverde (2010b)
$pdef$	Annual probability of default	0.03	Bernanke et al. (1999)
μ	Bankruptcy costs	0.15	Fernández-Villaverde (2012)
$\bar{\gamma}^e = \bar{\gamma}^{e*}$	Entrepreneurs exit coefficient	3.67	Fernández-Villaverde (2010b)
τ_l	Periphery labor income tax rate	0.22	Bozou and Creel (2023)
τ_l^*	Core labor income tax rate	0.25	Bozou and Creel (2023)
τ_r	Periphery capital gain tax rate	0.28	Capital gain tax rate Spain 2023
τ_r^*	Core capital gain tax rate	0.26	Capital gain tax rate Germany 2023
$\Pi = \Pi^* = \Pi_P = \Pi_C$	Target gross inflation	1.005	Fernández-Villaverde (2012)
$l = l^*$	Time devoted to work	1/3	Fernández-Villaverde (2012)
$q = q^*$	Tobin's q. Price of capital	1	Fernández-Villaverde (2010b)
$\frac{\bar{b}}{k} = \frac{\bar{b}^*}{k^*}$	Loan-to-capital	1/3	Fernández-Villaverde (2010b)
$\frac{g}{y} = \frac{g^*}{y^*}$	Public spending-to-GDP	0.2	Gomes and Seoane (2018)
$\frac{ig}{y}$	Periphery public investment-to-GDP	0.03	OCDE data: public investment to GDP Spain 2022
$\frac{ig^*}{y^*}$	Core public investment-to-GDP	0.025	OCDE data: public investment to GDP Germany 2022
$\frac{d}{y}$	Public debt-to-GDP in the periphery	0.9	Bozou and Creel (2023)
$\frac{d^*}{y^*}$	Public debt-to-GDP in the core	0.6	Bozou and Creel (2023)
$S"[1]$	Capital adjustment costs	14.477	Fernández-Villaverde (2012)
$\gamma_\Pi (1 - \gamma_R)$	Response of intervention rate to changes in inflation	1.5	Fernández-Villaverde (2012)
$d_g = d_g^*$	Response of public spending to changes in public debt-to-GDP	-0.01	Own calibration to obtain determinacy
$d_{ig} = d_{ig}^*$	Response of public investment to changes in public debt-to-GDP	-0.04	Own calibration to obtain determinacy
$\frac{c}{y}$	Steady state of private consumption-to-GDP in the periphery	0.59	From current parameter calibration
$\frac{c^*}{y^*}$	Steady state of private consumption-to-GDP in the core	0.65	From current parameter calibration
$\frac{i}{y}$	Steady state of private investment-to-GDP in the periphery	0.15	From current parameter calibration
$\frac{i^*}{y^*}$	Steady state of private investment-to-GDP in the core	0.15	From current parameter calibration

5. Effect of NGEU funds on inequality

In this section, we compare the effects on inequality generated by different scenarios of reception and use of the NextGeneration EU funds, introduced into the model as exogenous fiscal shocks. First, we analyze the economic consequences for both countries of a shock that takes place in the periphery, as well as the change in these consequences when the shock occurs in the core. We observe, for both situations, the effects that the European aid has on the recipient country and the spillovers generated in the other part of the Monetary Union. This first level characterizing the analyzed scenarios implies that the considered shock will always be asymmetric. Thus, we shed new light on the benefits and drawbacks of allocating the funds to one country or another.

Second, based on the Recovery and Resilience Facility, we consider different forms of fund reception. On the one hand, we analyze the effects of these aids on inequality and on the economic context when received in the form of grants. In this case, the recipient country does not experience an increase in its debt as a result of the fiscal shock but does have an additional source of public income to carry out reforms and investments. On the other hand, we study whether these effects vary significantly when the funds take the form of loans borrowed to the requesting Member States, so that their public debt goes up by the amount of the funds received.

Third and last, considering the different options for allocating the NextGeneration EU funds, we distinguish two alternatives in our analysis: The first consists of using the funds as non-productive expenditures; and the second consists of using the funds for public investment projects, also known as productive expenditures. Therefore, we introduce the model's shock either through the non-productive government spending rule or through the productive government spending rule, respectively. The scenarios are designed to show polar cases but, of course, Member States could choose to combine them.

Below, we analyze the results for each of the NGEU scenarios considered.

5.1. NGEU funds to the periphery

To assess the effects of the NGEU program in the periphery of the union, we analyze the response of the model economy to different types of fiscal shocks under two alternative scenarios: Reception of funds in the form of loans and reception of funds in the form of grants. In the latter case, public liabilities are not affected by the fiscal impulse. Figures 2 and 3 provide the results of the scenarios where the fiscal shocks take place in the peripheral country.

When the periphery receives a positive exogenous shock, either from non-productive public spending or public investment (representing, as previously indicated, the use of NGEU funds), the GDP of the peripheral region increases significantly, regardless of whether the shock increases public debt levels. This is primarily due to the direct impact that public spending and investment have on aggregate demand. Furthermore, the well-known crowding-out effect on private consumption takes place, although this does not cause significant damage to the level of production. This result is in line with Davig and Leeper (2011), who explain that the combination of active monetary policy with passive fiscal policy (as is the case in our model) leads to a tax increase and, therefore, a negative wealth effect that reduces private consumption.

Moreover, in an economy with sticky prices, these fiscal impulses, which are demand shocks, imply an increase in inflation in the region where they occur. Despite the opposite effect on inflation in the core country, which prevents the aggregate EMU inflation from rising significantly, the active nature of monetary policy causes the nominal interest rate to increase.

Active monetary policy interacts with fiscal stimulus, amplifying the latter's effects on private consumption. It can be observed that the crowding-out effect on private consumption generated by the increase in public spending is further reinforced by the rise in the monetary policy rate. This raises the real rate and induces Ricardian consumers to postpone consumption and increase their savings. This result is consistent with Andersen et al. (2023) that observe that increases in the interest rate might reduce households inequality. Also, contrary to the popular belief that high inflation especially harms the poor and according to Menna and Tirelli (2017), we find that inflation and inequality are inversely related.

This substitution effect explains a significant portion of the decline in aggregate consumption as a consequence of the decrease in consumption by Ricardian households. Non-Ricardian households, lacking the ability to save, are not affected by changes in financial market interest rates. In line with this result, McKay and Wolf (2023) conclude that the transmission channels of monetary policy differ across heterogeneous households. Additionally, because output is demand-determined, the demand for labor increases. As the real wage rises, households work harder so, since non-Ricardian households consume all their income, the increase in labor supply raises consumption of non-Ricardian households. This result is consistent with Gali et al. (2007) that find that the presence of liquidity constrained consumers makes aggregate consumption more sensitive to current labor income. Both effects in Ricardian and non-Ricardian consumption are reflected in a lower Gini index, as depicted in figures 2 and 3. Therefore, a main result is that when the peripheral country receives the NGEU funds, consumption inequality goes down in the periphery, no matter the kind of fiscal shock considered. We can thus conclude that fiscal stimulus affects inequality through the crowding-out effect it generates on Ricardian households' consumption, combined with an increase in labor income that leads to higher consumption by non-Ricardian consumers. This is further reinforced by active monetary policy, which, by raising interest rates, triggers an intertemporal substitution effect, amplifying the decline in Ricardian consumption even further. The result is a lower consumption Gini index in the country receiving the fiscal stimulus.

The negative correlation between public expenditure and inequality aligns with recent empirical evidence. For instance, Sánchez and Pérez-Corral (2018), through the estimation of dynamic panel models for the 28 Member States of the European Union, demonstrate a negative correlation between social public spending and income inequality during the period 2005–2014. By estimating a dynamic panel model for a sample of 122 countries, Sidek (2021) also concludes that public expenditure reduces inequality.

The core country's economy experiences negative spillover effects from the shock in the periphery. Both countries are connected through international goods and financial markets, transmission channels to the core of the effects of the shock in the periphery. This result is consequence of the basic modeling framework that considers only two countries within the monetary union. A multi-country setting could reflect positive spillovers due to the import demand (Pfeiffer et al, 2021) and could enable the identification of other potential non-linear cross-country spillovers (Corsetti et al. 2010 or Benchimol and Ivashchenko, 2021).

There is a capital outflow from the core country to the peripheral country due to the economic expansion in the latter. As a consequence, the GDP of the core country declines, along with consumption, private investment, and public spending. Then, because taxes are proportional to GDP, public debt increases in the core. The core country's recession, combined with the price increase in the peripheral country, results in a deterioration of the terms of trade, which in turn depresses net exports. This international channel, therefore, mitigates the expansionary effect of European funds in the peripheral country. Besides, labor demand decreases in the core country bringing down real wages and,

consequently, household's income, causing non-Ricardian consumers to cut back their consumption by more than Ricardian consumers. As a consequence, consumption inequality increases in the core, what is reflected in a higher Gini index (see figures 2 and 3).

5.1.1. Alternative scenarios for a non-productive public spending shock in the periphery

Figure 2 depicts the impulse response function of a non-productive public spending shock in the periphery. We distinguish two alternative scenarios: NGEU funds take the form of grants or the form of loans. The main observable difference between both situations is that private investment increases in the periphery when the funds are received as a grant (solid line) but plummets when the funds are received as a loan (dashed line). The explanation for this lies in the effect of this shock on public investment. In the scenario where the funds increase sovereign debt, the fiscal rule determining public investment lowers it in order to stabilize the government's budget. However, when the funds are received as a grant (solid line), the increase in GDP is not accompanied by an increase in government liabilities, so public investment grows in line with the economic growth experienced. The increase in government investment will generate greater accumulation of public capital. Then, private investment reacts by following the same trajectory as public investment. Recent empirical studies also reflect this positive relationship between public and private capital (Alloza et al, 2022; Matvejevs and Tkacevs, 2023).

Thus, due to this private investment rise, the solid line represents a scenario (grants) in which the increase of the peripheral country's output is more permanent than the increase in the peripheral output depicted by the dashed line (loans) scenario. This result coincides with that of Bozou and Creel (2023) that find more effective to finance the fiscal stimulus by grants. Furthermore, the funds received in the form of grants amplify the effects of the fiscal shock on both Ricardian and non-Ricardian consumption, such that consumption inequality drops to a greater extent than if the funds are in the form of loans.

It is remarkable that the grant scenario, which benefits the peripheral country the most, is the one that entails the largest core country gap between Ricardian and non-Ricardian consumption, so inequality in the core country becomes more pronounced (see solid line of Figure 2).

5.1.2. Alternative scenarios for a public investment shock in the periphery

The alternative scenarios for a productive government spending in the periphery are shown in Figure 3. In this case, since the shock itself implies a direct increase in public investment, private investment of the peripheral country goes up in both scenarios, regardless of whether the increase in public investment leads to growth in the periphery sovereign debt (dashed line) or not (solid line). Compared to the cases depicted in Figure 2, a public investment shock in the periphery raises its private investment by more, so the positive effects on the peripheral GDP are more enduring. This result agrees with Bańkowski et al. (2021) and Bozou and Creel (2023), who find that the use of the funds as productive spending bring more positive effects to the macroeconomy.

Under this shock, despite the improvement in economic activity, consumption inequality does not decrease as much as in the case of a non-productive public spending shock, as depicted in the scenarios of Figure 2. The intuition behind this is that the growth of public and private investment leads to greater capital accumulation in the economy and an increase in non-labor income. Therefore, in the scenarios presented in Figure 3, the rise in aggregate consumption has a greater influence from Ricardian consumption compared to scenarios in Figure 2.

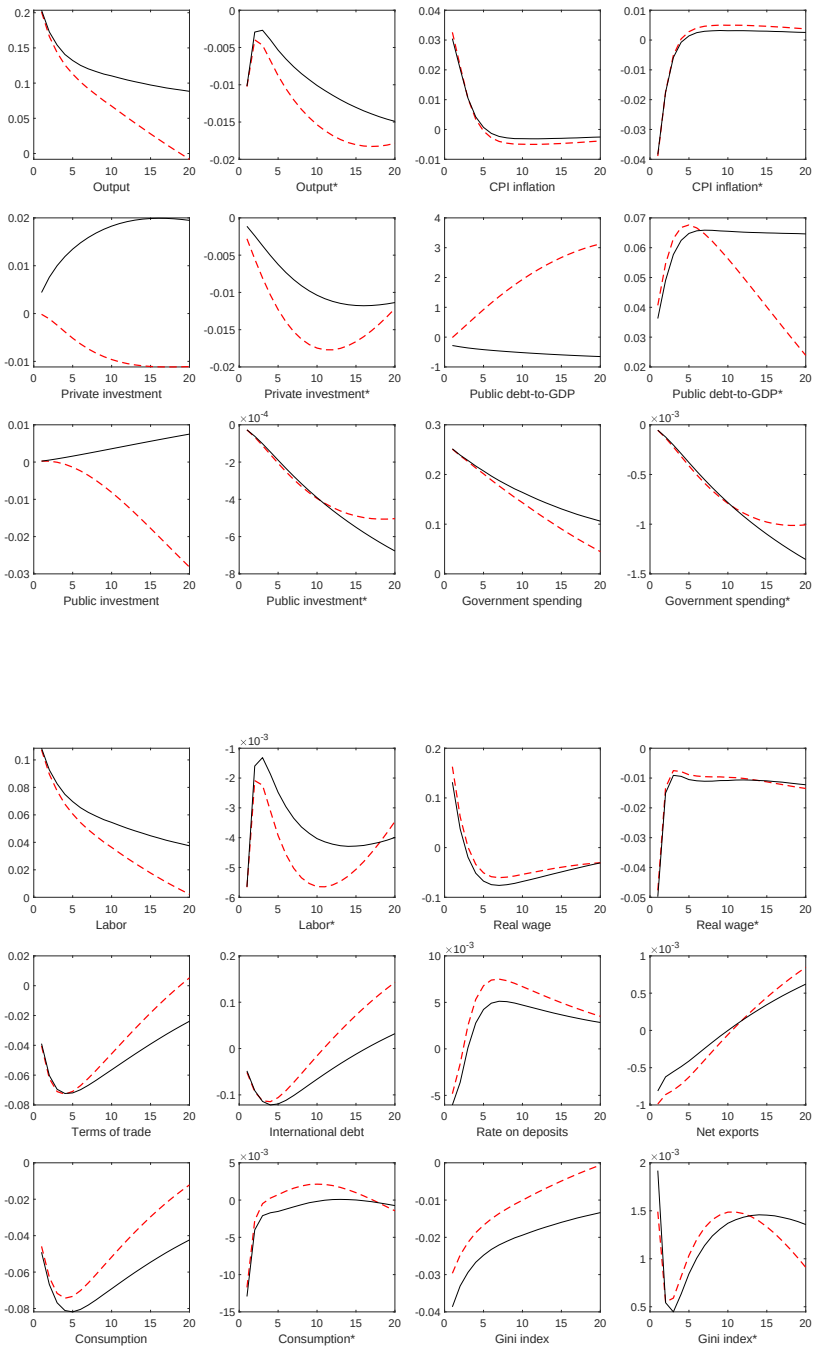

Figure 2. IRFs to a non-productive government spending shock in the periphery.

Note: Variables are expressed in percentage points of deviations from steady state. Core country variables are denoted with $*$. The dashed line represents the NGEU funds received in the form of loans. The solid line represents the NGEU funds received in the form of grants.

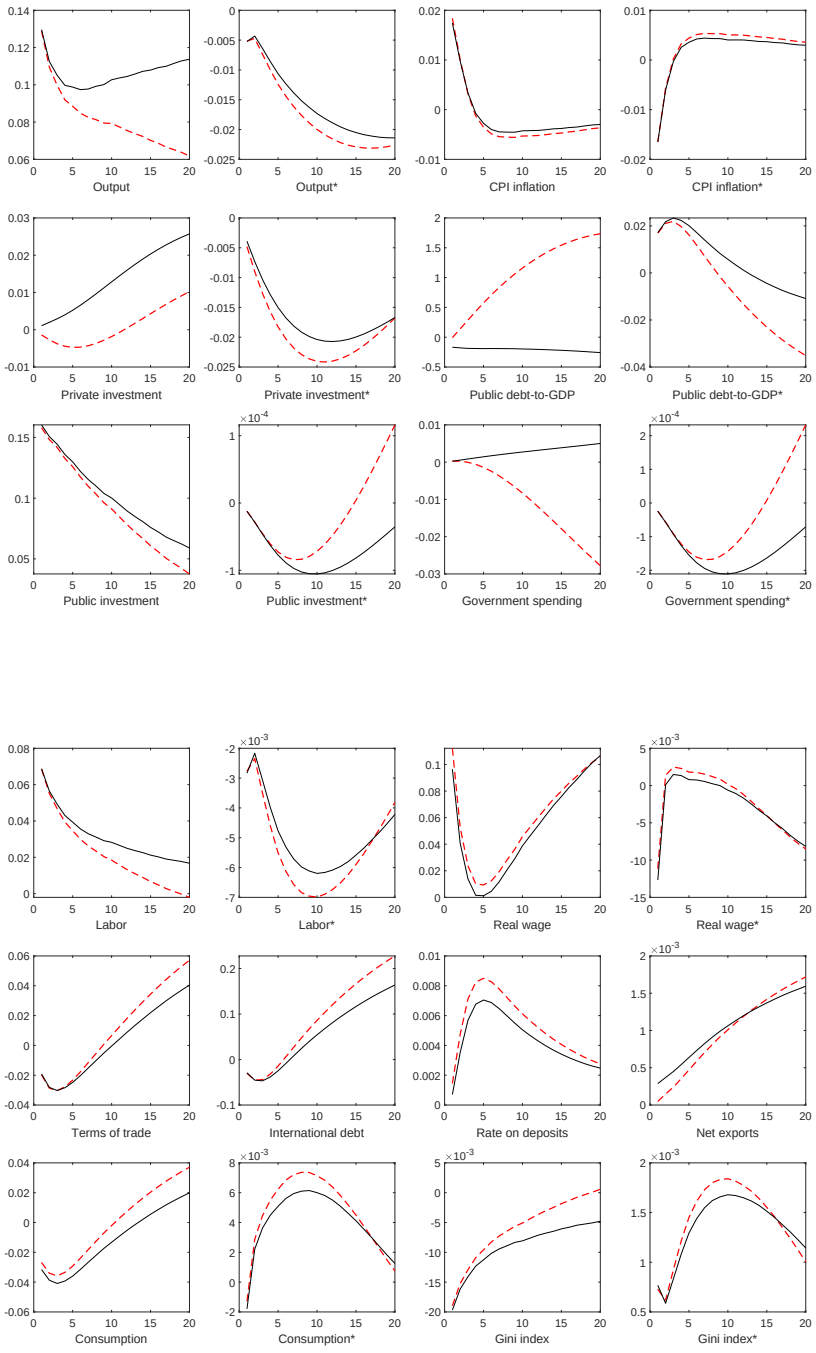

Figure 3. IRFs to a productive government spending (public investment) shock in the periphery.

Note: Variables are expressed in percentage points of deviations from steady state. Core country variables are denoted with $*$. The dashed line represents the NGEU funds received in the form of loans. The solid line represents the NGEU funds received in the form of grants.

The spillover effects of the peripheral shock does not vary significantly across the scenarios presented in Figure 3, implying that for the core country's economy, whether the funds received by the periphery are grants or loans, is of little relevance. By contrast, the economic consequences in the core country do vary depending on whether the periphery uses the European funds for public investment or for non-productive expenditure projects. Concretely, the GDP of the core within the monetary union decreases more when the periphery increases its public investment (scenarios of Figure 3), primarily due to a larger decline in private investment in the core caused by the increased investment opportunities that the NGEU funds provide to the peripheral country. Furthermore, in Figure 3, the decline in net exports from the periphery is smaller that in Figure 2 because of a reduction in imports due to the government's productive use of the funds. This also contributes to a greater deterioration in the core's GDP.

5.2. NGEU funds to the core

Figures 4 and 5 show the impulse response functions for the cases in which the core country receives the European aids as part of the NGEU program. Similarly to the case where the peripheral country received the funds, when it is the core country that receives them, the latter experiences an economic boom and reduces consumption inequalities among its households.

In this case, for the recipient country of the funds, the effects analyzed in section 5.1 are replicated. We again observe a positive relationship between public and private investment in the economy where the analyzed shock occurs. We also find a negative relation between inflation a inequality (Menna and Tirelli, 2017). Likewise, it can be seen that, once again, the reception of NGEU funds in the form of grants (solid line) brings more permanent positive effects for economic activity and inequality to the recipient country (the core) than the European aids received through loans (dashed line). In the following section, we provide a more detailed analysis for each of the 4 scenarios considered for the case where the core country is the recipient of the NGEU funds.

5.2.1. Non-productive public expenditure shock in the core

In this section, we analyze the impulse response functions after a public investment shock in the core, comparing the scenarios of receiving funds through grants versus receiving them through loans. These results are shown in Figure 4.

The economic consequences for the core country under this type of fiscal shock are the same as those experienced by the periphery when the latter receives the NGEU funds and uses them as productive public expenditure. In fact, the main differences compared to the case where the shock occurs in the periphery lie in the spillover effects on the non-recipient country. The first noticeable aspect is the significant drop in the peripheral GDP and private consumption.

Compared to the core, the periphery's economy relies on higher levels of public debt and holds a debtor position relative to the other region of the EMU. These characteristics imply greater financial fragility in the periphery, which is reflected in a larger collapse in its economic activity (due to capital outflows to the core) when the core country receives the NGEU funds. Since taxes are proportional, the pronounced GDP decline in the periphery leads to lower tax revenue and a significant increase in sovereign debt in this region. Additionally, consumption inequality in the periphery increases considerably, mainly due to the drop in employment and in labor income, the only source of revenues for non-Ricardian consumers.

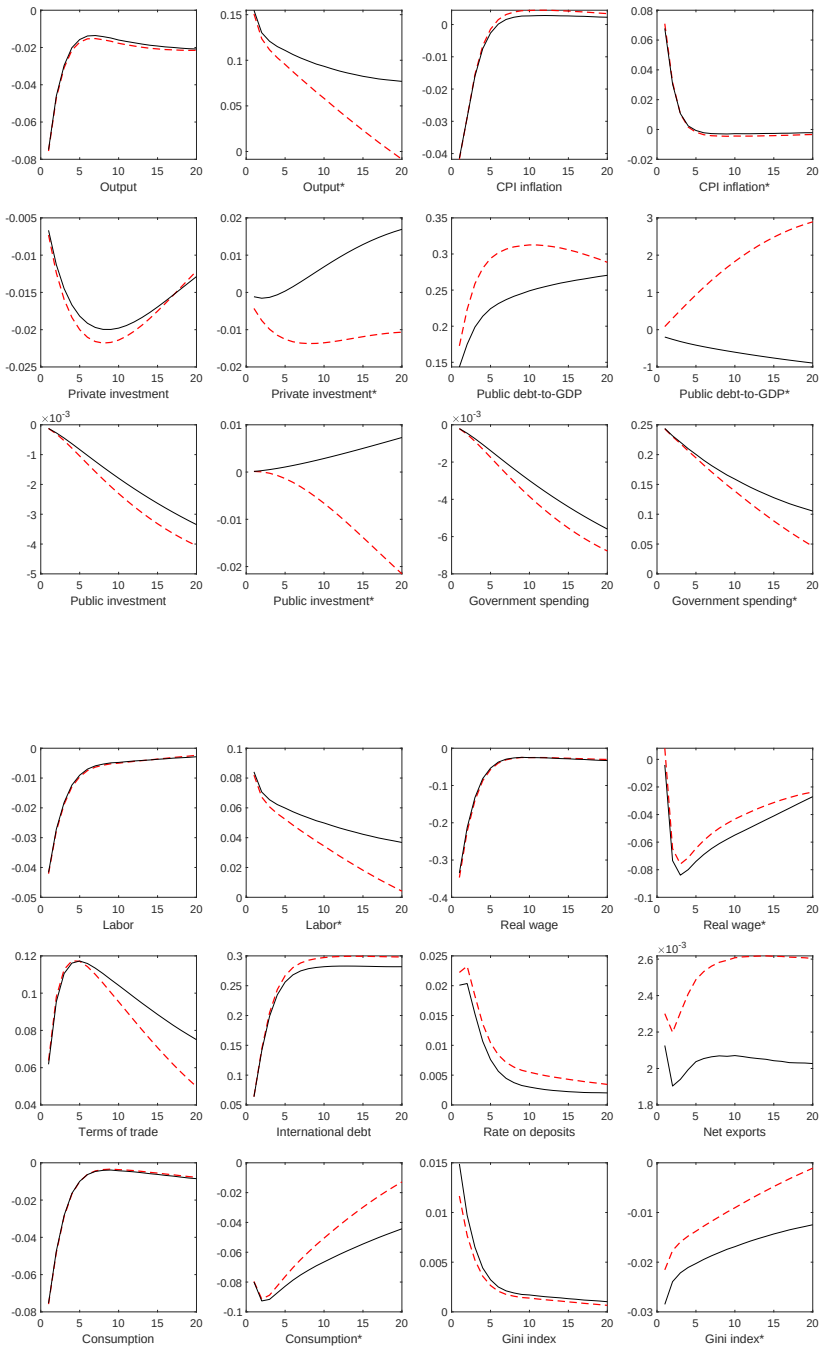

Figure 4. IRFs to a non-productive government spending shock in the core.

Note: Variables are expressed in percentage points of deviations from steady state. Core country variables are denoted with $*$. The dashed line represents the NGEU funds received in the form of loans. The solid line represents the NGEU funds received in the form of grants.

The fiscal shock in the core implies a greater response of prices, with inflation rising significantly in this country. For this reason, the active monetary policy strategy involves a larger increase in the interest rate than in the case of a periphery shock. Consequently, the decline of private consumption in both countries is greater when the core receives the European aid. Therefore, monetary policy once again generates a transmission mechanism for fiscal stimulus that further reduces private consumption, with this effect being more pronounced in this particular case, where the core economy receives the NGEU funds.

5.2.2. Public investment shock in the core

When the core country receives European funds and uses them to increase its public investment, the increase in the core's GDP is less pronounced but more permanent than when the funds are used for non-productive spending. The effects of this shock can be found in Figure 5. The improvement in investment opportunities brought about by this shock in public investment leads to an increase in private consumption and private investment in the core , which contributes to a longer-lasting positive impact on its output. Furthermore, this generates more moderate spillover effects in the peripheral country, which are reflected in a more gradual decline in GDP, inflation, and private consumption in this region compared to the shock on non-productive spending. Again, inequality is less reduced in the core when the funds are used for productive spending, but the Gini index also increases less in the periphery.

In this scenario, both the receipt of grants and loans by the core are more detrimental to the periphery than the economic deterioration suffered by the core when the funds are received by the former. However, the realization of the funds as public investment provides some relief to the crisis experienced in the peripheral country.

6. Robustness analysis

In this section, we present two robustness analysis of parameter calibration. First, we examine first- and second-order moments of the major economic variables in light of stylized facts and empirical evidence. In a second phase, we conduct a sensitivity analysis of the Taylor rule parameter to shed light on the interaction between fiscal and monetary policy in response to this type of fiscal stimulus.

6.1. First and second order moments

Table 3 presents the steady-state values of the major variables relative to GDP, as determined by the model's calibration, for both the peripheral and core regions. These values are then compared with the historical series (1999–2023) of the same variables for Spain and Germany, which represent these two regions within the model. The simulations are performed using a first-order approximation.

It can be observed that the steady-state values derived from our calibration are consistent with the historical data. In the case of net exports, the discrepancy arises from the fact that our model considers only two countries, which necessarily implies that they must exhibit the same value but with opposite signs.

Tables 4 to 11 display the correlation matrix of fiscal variables, GDP, and inequality in our model. Across all scenarios, the model dynamics reveal a negative correlation between GDP and inequality, the latter measured by the Gini index. This finding is consistent with empirical papers such as Persson and Tabellini (1994), Alesina and Rodrik (1994), or Sukiassyan (2007), among others.

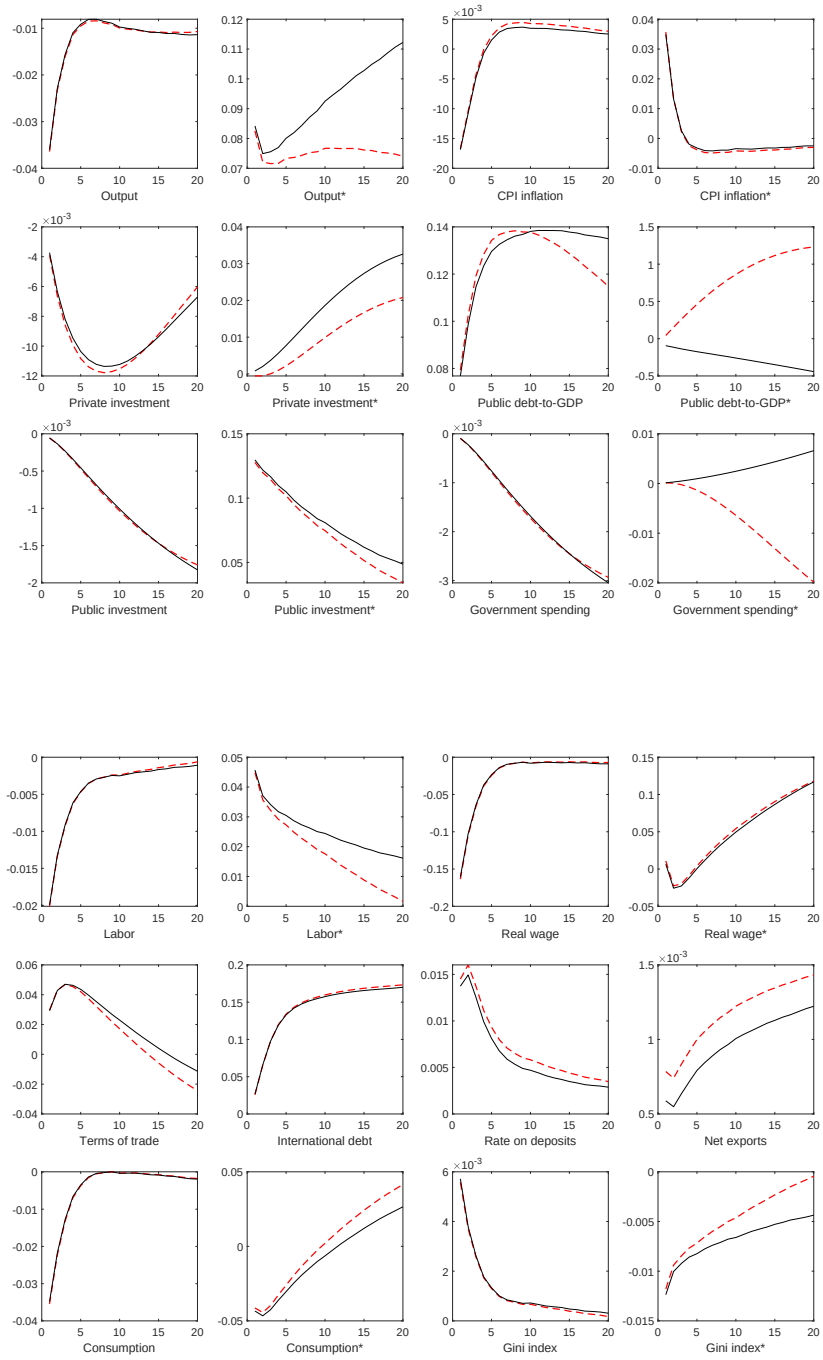

Figure 5. IRFs to a productive government spending (public investment) shock in the core.

Note: Variables are expressed in percentage points of deviations from steady state. Core country variables are denoted with $*$. The dashed line represents the NGEU funds received in the form of loans. The solid line represents the NGEU funds received in the form of grants.

Table 3. Steady state and historical average matching. Eurostat

	Steady state		Historical average	
	Periphery	Core	Spain	Germany
GDP	1.00	1.00	1.00	1.00
Private consumption-to-GDP	0.65	0.60	0.58	0.55
Private investment-to-GDP	0.15	0.15	0.20	0.18
Public consumption-TO-GDP	0.20	0.20	0.19	020
Public investment-to-GDP	0.03	0.03	0.03	0.03
Net exports	−0.03	0.03	−0.001	0.05
Monetary policy rate	0.02	0.02	0.01	0.01

Regarding fiscal variables, Tables 4 to 11 also reflect correlations aligned with the literature and empirical evidence. Specifically, Menguy (2022) identifies a series of stylized facts concerning fiscal indicators in countries of the European Union following the fiscal stimulus measures implemented in response to COVID-19. Our theoretical analysis yields results consistent with those findings. For example, the proportional tax structure in our model generates a strong positive relationship between government revenue (tax collection) and GDP in both countries across all evaluated scenarios. This outcome is in line with the empirical analysis of Menguy (2022).

Tables 4 to 11 further show that, in the country receiving fiscal stimulus, there is a negative correlation between GDP and government debt. This occurs because, when stimulus funds are provided in the form of loans (see Tables 4 to 7), the impact of fiscal stimulus on debt is offset by increased tax revenues resulting from higher GDP. This inverse relationship is even stronger when fiscal stimulus takes the form of grants, as they do not generate public debt accumulation (see Tables 8 to 11). Again, the European Union data analyzed by Menguy (2022) confirm this negative relationship.

The fiscal policy instrument employed in each scenario of our analysis (public spending or public investment) is positively associated with GDP, a result consistent with Menguy (2022) and indicative of a positive fiscal multiplier (further citations needed).

The crowding-out effect on consumption after the exogenous government expenditures shock (Davig and Leeper, 2011) is reflected in the negative correlation between public spending and private consumption in the country receiving European funds allocated to increased public spending (see Tables 4, 5, 8, and 9 for the peripheral country and Tables 6, 7, 10, and 11 for the core country). However, when European aid is channeled through increased public investment, the recipient country does not experience crowding-out effects on private investment. In contrast, private investment may even be stimulated by higher government investment. This result is particularly relevant as it aligns with recent empirical evidence on the positive correlation between private and public investment (Alloza et al, 2022; Matvejevs and Tkacevs, 2023).

We follow King and Rebelo (1999) and compute the relative volatility with respect to GDP of the main macroeconomic and fiscal variables in the model, which are shown in Table 12. The first two columns present the scenarios in which NGEU funds are received in the form of loans and are used to increase public expenditure (column 1) or public investment (column 2). Columns 3 and 4 of the table replicate the latter uses of the funds, respectively, but for cases in which the aid is granted in the form of subsidies.

The table displays the relative standard deviations of the peripheral variables for the scenarios in which this country receives the European aids, as well as the relative standard deviations of the core variables for the cases in which it is the core country that receives the funds.

The figures obtained are consistent with well-established stylized facts: The volatility of private consumption is lower than that of GDP, while the relative volatilities exceed 1 in the case of the fiscal instruments acting as transmission channels for NGEU Funds (public expenditure, public investment, and public debt).

Table 4. Correlation matrix - NGEU loans to increase public spending in the periphery.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.395	0.974	0.492	-0.603	0.816	0.896	-0.999
$\frac{d_t}{y_t}$	-0.395	1.000	-0.299	-0.258	-0.013	-0.315	-0.541	0.423
g_t	0.974	-0.299	1.000	0.581	-0.766	0.910	0.774	-0.973
$i_{g,t}$	0.492	-0.258	0.581	1.000	-0.726	0.653	0.205	-0.488
c_t	-0.603	-0.013	-0.766	-0.726	1.000	-0.905	-0.190	0.603
i_t	0.816	-0.315	0.910	0.653	-0.905	1.000	0.516	-0.823
tax_t	0.896	-0.541	0.774	0.205	-0.190	0.516	1.000	-0.898
gi_t	-0.999	0.423	-0.973	-0.488	0.603	-0.823	-0.898	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	0.286	-0.594	-0.594	0.647	0.680	0.965	-0.981
$\frac{d_t^*}{y_t^*}$	0.286	1.000	-0.390	-0.390	0.359	0.546	0.153	-0.361
g_t^*	-0.594	-0.390	1.000	1.000	-0.122	-0.802	-0.438	0.523
$i_{g,t}^*$	-0.594	-0.390	1.000	1.000	-0.122	-0.802	-0.438	0.523
c_t^*	0.647	0.359	-0.122	-0.122	1.000	0.225	0.674	-0.660
i_t^*	0.680	0.546	-0.802	-0.802	0.225	1.000	0.486	-0.659
tax_t^*	0.965	0.153	-0.438	-0.438	0.674	0.486	1.000	-0.965
gi_t^*	-0.981	-0.361	0.523	0.523	-0.660	-0.659	-0.965	1.000

Table 5. Correlation matrix - NGEU loans to increase public investment in the periphery.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.295	0.454	0.974	-0.511	0.176	0.895	-0.981
$\frac{d_t}{y_t}$	-0.295	1.000	-0.258	-0.314	0.201	0.789	-0.472	0.470
g_t	0.454	-0.258	1.000	0.570	-0.771	-0.331	0.185	-0.450
$i_{g,t}$	0.974	-0.314	0.570	1.000	-0.690	0.122	0.793	-0.957
c_t	-0.511	0.201	-0.771	-0.690	1.000	0.073	-0.136	0.494
i_t	0.176	0.789	-0.331	0.122	0.073	1.000	0.028	-0.018
tax_t	0.895	-0.472	0.185	0.793	-0.136	0.028	1.000	-0.929
gi_t	-0.981	0.470	-0.450	-0.957	0.494	-0.018	-0.929	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	-0.052	-0.676	-0.676	0.623	0.616	0.921	-0.977
$\frac{d_t^*}{y_t^*}$	-0.052	1.000	-0.276	-0.276	-0.632	0.678	-0.396	-0.004
g_t^*	-0.676	-0.276	1.000	1.000	-0.038	-0.763	-0.439	0.576
$i_{g,t}^*$	-0.676	-0.276	1.000	1.000	-0.038	-0.763	-0.439	0.576
c_t^*	0.623	-0.632	-0.038	-0.038	1.000	-0.212	0.852	-0.615
i_t^*	0.616	0.678	-0.763	-0.763	-0.212	1.000	0.272	-0.615
tax_t^*	0.921	-0.396	-0.439	-0.439	0.852	0.272	1.000	-0.909
gi_t^*	-0.977	-0.004	0.576	0.576	-0.615	-0.615	-0.909	1.000

Table 6. Correlation matrix - NGEU loans to increase public spending in the core.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.379	-0.410	-0.410	0.988	0.329	0.997	-0.987
$\frac{d_t}{y_t}$	-0.379	1.000	-0.091	-0.091	-0.474	-0.904	-0.361	0.325
g_t	-0.410	-0.091	1.000	1.000	-0.425	-0.240	-0.436	0.498
$i_{g,t}$	-0.410	-0.091	1.000	1.000	-0.425	-0.240	-0.436	0.498
c_t	0.988	-0.474	-0.425	-0.425	1.000	0.425	0.991	-0.985
i_t	0.329	-0.904	-0.240	-0.240	0.425	1.000	0.313	-0.306
tax_t	0.997	-0.361	-0.436	-0.436	0.991	0.313	1.000	-0.996
gi_t	-0.987	0.325	0.498	0.498	-0.985	-0.306	-0.996	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	-0.233	0.978	0.534	-0.822	-0.057	0.949	-1.000
$\frac{d_t^*}{y_t^*}$	-0.233	1.000	-0.168	-0.242	0.032	0.744	-0.348	0.254
g_t^*	0.978	-0.168	1.000	0.597	-0.922	-0.067	0.863	-0.977
$i_{g,t}^*$	0.534	-0.242	0.597	1.000	-0.688	-0.039	0.378	-0.536
c_t^*	-0.822	0.032	-0.922	-0.688	1.000	0.051	-0.602	0.820
i_t^*	-0.057	0.744	-0.067	-0.039	0.051	1.000	-0.093	0.079
tax_t^*	0.949	-0.348	0.863	0.378	-0.602	-0.093	1.000	-0.951
gi_t^*	-1.000	0.254	-0.977	-0.536	0.820	0.079	-0.951	1.000

Table 7. Correlation matrix - NGEU loans to increase public investment in the core.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.383	-0.190	-0.190	0.939	0.007	0.980	-0.953
$\frac{d_t}{y_t}$	-0.383	1.000	-0.331	-0.331	-0.081	-0.758	-0.400	0.585
g_t	-0.190	-0.331	1.000	1.000	-0.432	0.815	-0.342	0.221
$i_{g,t}$	-0.190	-0.331	1.000	1.000	-0.432	0.815	-0.342	0.221
c_t	0.939	-0.081	-0.432	-0.432	1.000	-0.330	0.941	-0.841
i_t	0.007	-0.758	0.815	0.815	-0.330	1.000	-0.080	-0.117
tax_t	0.980	-0.400	-0.342	-0.342	0.941	-0.080	1.000	-0.973
gi_t	-0.953	0.585	0.221	0.221	-0.841	-0.117	-0.973	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	0.050	0.460	0.960	-0.785	0.338	0.933	-0.959
$\frac{d_t^*}{y_t^*}$	0.050	1.000	-0.240	-0.151	0.227	0.944	-0.163	0.233
g_t^*	0.460	-0.240	1.000	0.579	-0.744	0.027	0.330	-0.527
$i_{g,t}^*$	0.960	-0.151	0.579	1.000	-0.916	0.153	0.880	-0.977
c_t^*	-0.785	0.227	-0.744	-0.916	1.000	-0.071	-0.626	0.830
i_t^*	0.338	0.944	0.027	0.153	-0.071	1.000	0.095	-0.065
tax_t^*	0.933	-0.163	0.330	0.880	-0.626	0.095	1.000	-0.954
gi_t^*	-0.959	0.233	-0.527	-0.977	0.830	-0.065	-0.954	1.000

Table 8. Correlation matrix - NGEU grants to increase public spending in the periphery.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.762	0.971	-0.261	-0.412	0.452	0.997	-0.999
$\frac{d_t}{y_t}$	-0.762	1.000	-0.863	-0.243	0.839	-0.910	-0.713	0.758
g_t	0.971	-0.863	1.000	-0.215	-0.613	0.615	0.957	-0.975
$i_{g,t}$	-0.261	-0.243	-0.215	1.000	-0.171	0.395	-0.314	0.290
c_t	-0.412	0.839	-0.613	-0.171	1.000	-0.930	-0.357	0.424
i_t	0.452	-0.910	0.615	0.395	-0.930	1.000	0.387	-0.449
tax_t	0.997	-0.713	0.957	-0.314	-0.357	0.387	1.000	-0.997
gi_t	-0.999	0.758	-0.975	0.290	0.424	-0.449	-0.997	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	-0.031	-0.534	-0.534	0.792	0.616	0.909	-0.994
$\frac{d_t^*}{y_t^*}$	-0.031	1.000	-0.353	-0.353	0.405	-0.267	-0.366	0.022
g_t^*	-0.534	-0.353	1.000	1.000	-0.277	-0.751	-0.512	0.562
$i_{g,t}^*$	-0.534	-0.353	1.000	1.000	-0.277	-0.751	-0.512	0.562
c_t^*	0.792	0.405	-0.277	-0.277	1.000	0.061	0.474	-0.762
i_t^*	0.616	-0.267	-0.751	-0.751	0.061	1.000	0.820	-0.664
tax_t^*	0.909	-0.366	-0.512	-0.512	0.474	0.820	1.000	-0.922
gi_t^*	-0.994	0.022	0.562	0.562	-0.762	-0.664	-0.922	1.000

Table 9. Correlation matrix - NGEU grants to increase public investment in the periphery.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.885	0.005	0.969	-0.464	0.357	0.906	-0.981
$\frac{d_t}{y_t}$	-0.885	1.000	-0.238	-0.944	0.801	-0.617	-0.611	0.830
g_t	0.005	-0.238	1.000	-0.043	-0.184	0.900	-0.290	0.190
$i_{g,t}$	0.969	-0.944	-0.043	1.000	-0.651	0.358	0.818	-0.964
c_t	-0.464	0.801	-0.184	-0.651	1.000	-0.530	-0.103	0.435
i_t	0.357	-0.617	0.900	0.358	-0.530	1.000	-0.013	-0.179
tax_t	0.906	-0.611	-0.290	0.818	-0.103	-0.013	1.000	-0.940
gi_t	-0.981	0.830	0.190	-0.964	0.435	-0.179	-0.940	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	-0.128	-0.622	-0.622	0.896	0.578	0.953	-0.991
$\frac{d_t^*}{y_t^*}$	-0.128	1.000	-0.251	-0.251	-0.359	0.607	-0.409	0.126
g_t^*	-0.622	-0.251	1.000	1.000	-0.266	-0.841	-0.452	0.560
$i_{g,t}^*$	-0.622	-0.251	1.000	1.000	-0.266	-0.841	-0.452	0.560
c_t^*	0.896	-0.359	-0.266	-0.266	1.000	0.187	0.944	-0.897
i_t^*	0.578	0.607	-0.841	-0.841	0.187	1.000	0.332	-0.564
tax_t^*	0.953	-0.409	-0.452	-0.452	0.944	0.332	1.000	-0.954
gi_t^*	-0.991	0.126	0.560	0.560	-0.897	-0.564	-0.954	1.000

Table 10. Correlation matrix - NGEU grants to increase public spending in the core.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.181	-0.621	-0.621	0.605	0.556	0.824	-0.961
$\frac{d_t}{y_t}$	-0.181	1.000	-0.236	-0.236	0.618	0.622	-0.702	0.415
g_t	-0.621	-0.236	1.000	1.000	-0.454	-0.702	-0.344	0.427
$i_{g,t}$	-0.621	-0.236	1.000	1.000	-0.454	-0.702	-0.344	0.427
c_t	0.605	0.618	-0.454	-0.454	1.000	0.796	0.076	-0.433
i_t	0.556	0.622	-0.702	-0.702	0.796	1.000	0.035	-0.333
tax_t	0.824	-0.702	-0.344	-0.344	0.076	0.035	1.000	-0.926
gi_t	-0.961	0.415	0.427	0.427	-0.433	-0.333	-0.926	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	-0.664	0.974	-0.356	-0.741	0.207	0.995	-1.000
$\frac{d_t^*}{y_t^*}$	-0.664	1.000	-0.734	-0.221	0.825	-0.842	-0.701	0.657
g_t^*	0.974	-0.734	1.000	-0.379	-0.872	0.294	0.991	-0.975
$i_{g,t}^*$	-0.356	-0.221	-0.379	1.000	0.268	0.442	-0.369	0.374
c_t^*	-0.741	0.825	-0.872	0.268	1.000	-0.532	-0.803	0.745
i_t^*	0.207	-0.842	0.294	0.442	-0.532	1.000	0.251	-0.199
tax_t^*	0.995	-0.701	0.991	-0.369	-0.803	0.251	1.000	-0.996
gi_t^*	-1.000	0.657	-0.975	0.374	0.745	-0.199	-0.996	1.000

Table 11. Correlation matrix - NGEU grants to increase public investment in the core.

	y_t	$\frac{d_t}{y_t}$	g_t	$i_{g,t}$	c_t	i_t	tax_t	gi_t
y_t	1.000	-0.340	-0.260	-0.260	0.976	-0.018	0.985	-0.970
$\frac{d_t}{y_t}$	-0.340	1.000	-0.302	-0.302	-0.167	-0.873	-0.397	0.516
g_t	-0.260	-0.302	1.000	1.000	-0.437	0.697	-0.366	0.291
$i_{g,t}$	-0.260	-0.302	1.000	1.000	-0.437	0.697	-0.366	0.291
c_t	0.976	-0.167	-0.437	-0.437	1.000	-0.227	0.970	-0.930
i_t	-0.018	-0.873	0.697	0.697	-0.227	1.000	-0.012	-0.119
tax_t	0.985	-0.397	-0.366	-0.366	0.970	-0.012	1.000	-0.991
gi_t	-0.970	0.516	0.291	0.291	-0.930	-0.119	-0.991	1.000
	y_t^*	$\frac{d_t^*}{y_t^*}$	g_t^*	$i_{g,t}^*$	c_t^*	i_t^*	tax_t^*	gi_t^*
y_t^*	1.000	-0.924	-0.003	0.948	-0.779	0.398	0.946	-0.959
$\frac{d_t^*}{y_t^*}$	-0.924	1.000	-0.238	-0.867	0.802	-0.630	-0.755	0.809
g_t^*	-0.003	-0.238	1.000	-0.240	0.300	0.688	-0.173	0.259
$i_{g,t}^*$	0.948	-0.867	-0.240	1.000	-0.917	0.202	0.902	-0.977
c_t^*	-0.779	0.802	0.300	-0.917	1.000	-0.204	-0.658	0.816
i_t^*	0.398	-0.630	0.688	0.202	-0.204	1.000	0.136	-0.135
tax_t^*	0.946	-0.755	-0.173	0.902	-0.658	0.136	1.000	-0.971
gi_t^*	-0.959	0.809	0.259	-0.977	0.816	-0.135	-0.971	1.000

Table 12. Relative standard deviations of major economic and fiscal variables to GDP under the different NGEU scenarios analyzed.

	NGEU as loans		NGEU as grants	
	Public spending	Public investment	Public spending	Public investment
y_t	1.00	1.00	1.00	1.00
$\frac{d_t}{y_t}$	4.94	4.79	2.15	2.20
g_t	1.24	0.06	1.18	0.03
$i_{g,t}$	0.04	1.19	0.01	1.18
c_t	0.35	0.30	0.34	0.31
i_t	0.03	0.04	0.10	0.10
tax_t	0.26	0.29	0.30	0.30
gi_t	0.15	0.16	0.20	0.17
y_t^*	1.00	1.00	1.00	1.00
$\frac{d_t^*}{y_t^*}$	5.81	5.51	2.06	1.72
g_t^*	1.51	0.06	1.45	0.03
$i_{g,t}^*$	0.04	1.45	0.01	1.44
c_t^*	0.56	0.58	0.53	0.57
i_t^*	0.02	0.15	0.07	0.20
tax_t^*	0.23	0.24	0.35	0.25
gi_t^*	0.15	0.15	0.19	0.16

6.2. Monetary-fiscal policy interaction

Benchimol (2024) alludes to the debate on the importance of adapting the Taylor rule to the central bank's needs at any given time instead of adhering to well-defined policy rules. Although the model considers only inflation targeting monetary policy because, according to Benchimol (2024), it achieves the best fit to historical data, it could also be of interest for future research to consider the benefits of monetary rules aimed at stabilizing nominal GDP.

Therefore, in this section, we conduct a sensitivity analysis of the monetary policy parameter that stabilizes inflation. This provides a deeper assessment of the interaction between monetary and fiscal policy following the receipt of NGEU funds through the applied model. The robustness test is presented for the case in which the peripheral country receives NGEU funds.

Considering that European aid materializes as fiscal stimulus in recipient countries, we now analyze how an active monetary policy, in the sense of Leeper (1991), can contribute to economic stability through its impact on GDP and the primary target variable of fiscal policy: the public debt-to-GDP ratio. To this end, based on the standard procedure of Iacobello (2005), we examine the variability of these two variables for different parameterizations of γ_Π within the interval [1.4,10]. This grid of values of the monetary policy parameter corresponds to inflation targeting rules in our model.

Figure 6 presents the results of this robustness analysis. In this figure, the two upper graphs correspond to the case in which NGEU funds are received as loans, implying an accumulation of public debt in the beneficiary country. The two lower graphs represent the scenarios in which European aids are received as grants without increasing public debt in recipient countries. The first column (left)

refers to the use of NGEU funds as non-productive public spending, whereas the second column (right) corresponds to their use as productive public spending. The plot colors become lighter as the value of γ_Π increases. Furthermore, the triangle in the plot indicates the point for $\gamma_\Pi = 1.5$, which is the calibration used in the model.

This choice of calibration for γ_Π is, on the one hand, a conventional value in the literature (Fernández-Villaverde, 2012) and, on the other hand, the value that enables greater stabilization of GDP in the case of a debt-accumulating fiscal stimulus, which is the most common case. Lower values of γ_Π correspond to a passive monetary policy that does not adhere to inflation targeting and when combined with debt-stabilizing (passive) fiscal policies, this results in indeterminacy (Davig and Leeper, 2011).

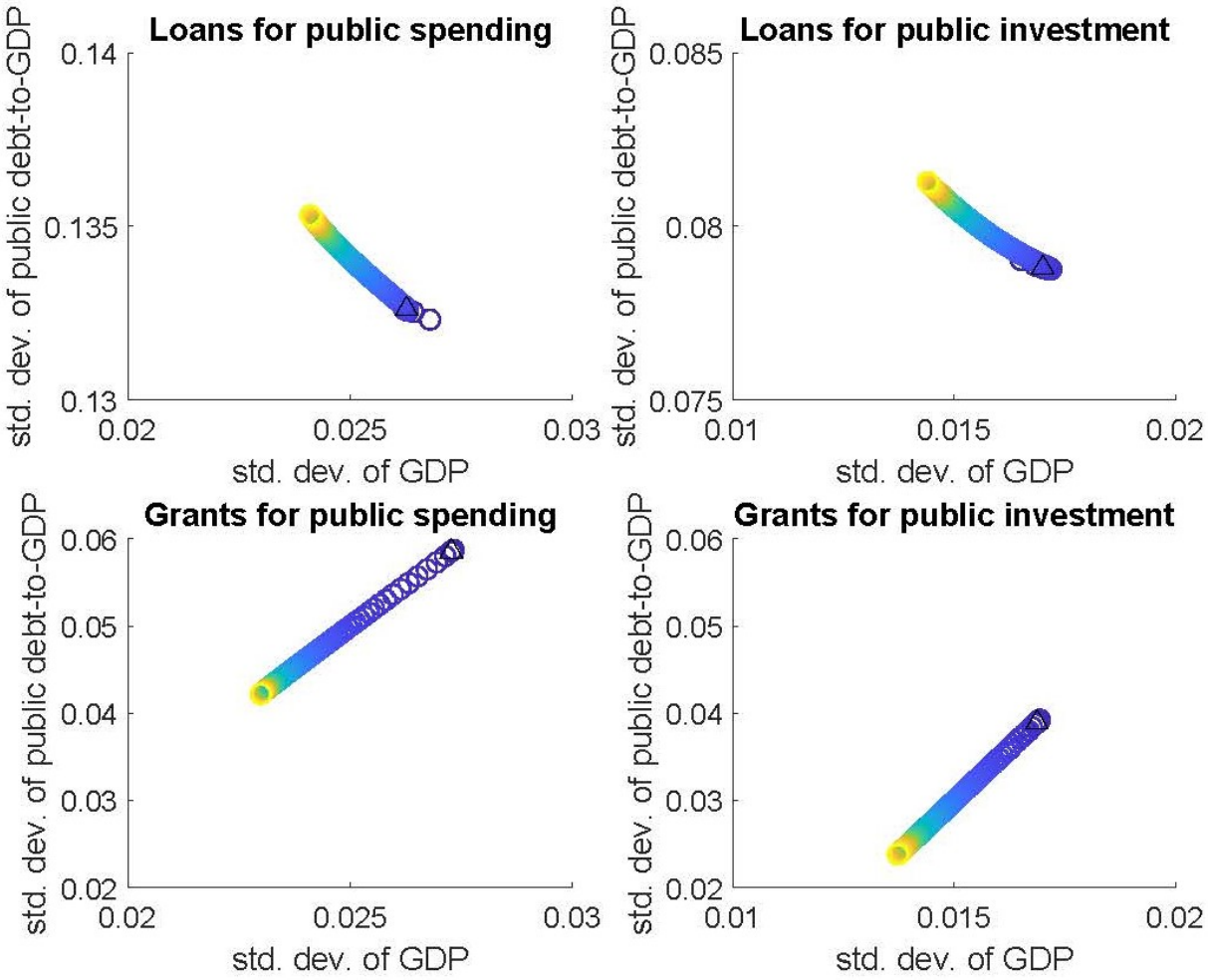

Figure 6. Validation analysis to alternative values of γ_Π after a NGEU fiscal stimulus to the periphery.

Note: The two upper graphs correspond to NGEU funds received as loans and the two lower graphs represent the NGEU received as grants. The left column refers to a non-productive public spending shock and the right column to a public investment shock. The plot becomes lighter with greater values of γ_Π. The triangle in the plot indicates current calibration of the policy parameter, that is $\gamma_\Pi = 1.5$.

In the case where funds are received as loans, there is a clear trade-off between public debt stability and GDP stability. This results from the interaction between the Taylor rule and the fiscal stimulus. Following this type of fiscal shocks, output and GDP increase in the country receiving the NGEU funds. This scenario leads to higher public debt. Monetary policy reacts by raising the interest rate. This increase reduces consumption by Ricardian households due to the intertemporal substitution effect, which counteracts GDP growth but amplifies the rise in public debt by lowering tax revenues, given that the model assumes proportional taxation. Consequently, as illustrated in the figure, a more aggressive monetary policy enhances GDP stability at the cost of greater public debt volatility.

Bianchi, Faccini and Melosi (2022) propose a coordinated strategy between fiscal and monetary policies, whereby the latter temporarily tolerates the higher inflation resulting from an increase in public spending. In line with their proposal, we have also identified a trade-off between inflation stability and public debt, which implies that to ensure lower volatility in sovereign debt, a less aggressive Taylor rule should be implemented, entailing a weaker interest rate response to price fluctuations.

If the funds are received as grants, the outcome of the interaction between fiscal and monetary policy is markedly different. In this case, a more aggressive interest rate response to inflation simultaneously stabilizes both GDP and public debt. The reason for this effect is that the aid does not lead to public debt accumulation, and when the fiscal stimulus increases GDP, proportional taxes cause government debt to decline. Thus, an interest rate hike offsets the impact of the stimulus on the evaluated variables. In this scenario, monetary policy effectively stabilizes the fiscal policy target variable.

7. Conclusions

We use a two-country New Keynesian model to represent the core and periphery regions of the EMU. Through exogenous fiscal shocks, the effects in both regions of the European Recovery and Resilience Facility program are replicated in the analysis. This theoretical study of different shocks enables us to compare a range of scenarios for receiving and using European funds and their consequences for the economic activity of both countries. As a major contribution of this analysis, we have also observed the effects of each of these shocks on consumption inequality, enabling us to draw conclusions regarding the impact of the NGEU funds on social sustainability through this specific measure.

The first relevant conclusion is that the effects of the European aid vary depending on how it is used. When the funds are used for non-productive public spending, their impact is more immediate but less durable compared to when they are used to increase public investment. We have also observed that an increase in public investment leads to a rise in private investment, which translates into higher levels of GDP. Therefore, national governments need to decide on the most appropriate fund usage strategy based on whether their reform objectives are more short-term or long-term oriented. Additionally, the form in which the aid is provided (grant or loan) is also crucial for the economic consequences in the EMU regions, as receiving funds in the form of grants amplifies the positive effects in the recipient country. To achieve a stronger recovery, the European Union should assess whether it is more beneficial for the aid to be primarily grants to the countries.

Another conclusion revealed by this analysis is that, despite the positive consequences for the economy receiving the funds, the spillover effects on the country that does not receive the aid always end up generating a recession in that region. Furthermore, the effects are even more harmful for the periphery when the funds are given to the core than vice versa. This is important because, although

no discrimination has been made between the periphery and the core when distributing the funds, the authorities involved in said distribution should be aware that spillovers are likely to hinder the recovery sought by each country. This result also reinforces the idea that the periphery needs more assistance than the core due to its financial weakness.

The analysis also suggests that coordination between fiscal and monetary policy must adapt to the manner in which fiscal stimulus is received. If debt is generated through financial aid from the European Union, an overly active monetary policy, while stabilizing GDP, would lead to greater volatility in sovereign debt. Conversely, if the funds are received through grants, a more aggressive monetary policy response to inflation would contribute to greater stability in both GDP and government liabilities.

Finally, this analysis enables us to draw conclusions regarding the impact of the funds on social sustainability. We have observed that the NGEU funds reduce household consumption inequality in the economy where they are received, especially when the aid takes the form of grant. Thus, in our setting, consumption inequality is countercyclical as it is in Eskelinen (2021). However, using the funds for productive public spending does not contribute as much to social sustainability as using them for non-productive spending. Therefore, governments of countries receiving the European aid should take this result into account, since it highlights the potential advantage of using the funds for non-productive spending when the fiscal policy objectives also involve social improvement. On the other hand, we also observe that the spillover effects in the country not receiving the funds lead to a deterioration in social sustainability through a greater gap in consumption among the different types of households considered.

As a final conclusion, we want to emphasize that the best scenario depends on the perspective from which it is observed. While using the funds for non-productive spending leads to less durable economic growth, it implies a significant improvement in the analyzed social sustainability variables. However, this analysis has not taken into account factors such as the political and institutional context or the capacity of different countries to absorb the European financial aid. Some scholars have raised concerns about the significance of these characteristics for the effective implementation of NGEU funds (Gros, 2021; Bisciari et al, 2021; Marques Santos et al, 2023). As a follow-up to this research, further exploration could be conducted into the variation in the speed of fund absorption among Member States.

On the other hand, it is necessary to consider how the funds in the form of grants will be financed, although there does not seem to be a direct debtor for this operation, it will soon be necessary to determine who will be the payer. In line with this, the distribution of the cost of these aids could lead to future research. This analysis also invites further exploration into the interaction of the European aids with alternative monetary policy rules or other already established policies such as macroprudential measures. Finally, as a follow up of this work, the model employed in this analysis could be enhanced by incorporating a multi-country framework, in line with Pfeiffer et al. (2021), which would enable a more accurate capture of the cross-country spillover effects generated by fiscal policy and financial markets. Such modeling could also prove valuable in representing a fund allocation process that accounts for country-specific endogenous conditions.

Author contributions

María Malmierca-Ordoqui: Methodology, Formal analysis, Investigation, Writing - Original Draft preparation, Project administration.

Carlos Arenas Laorga: Conceptualization, Resources, Validation, Visualization.

Marta del Río Caballero: Writing - Review and Editing, Supervision.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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Appendix A

Contract between financial intermediary and entrepreneur

The model includes a productivity shock ω_{t+1} that is lognormally distributed with a cumulative distribution function represented by $F(\omega, \sigma_{\omega,t})$, with $\mu_{\omega,t}$ being the average and $\sigma_{\omega,t}$ being the standard deviation of the distribution, where $E_t\omega_{t+1} = 1$. From the properties of the lognormal distribution:

$$E_t\omega_{t+1} = e^{\mu_{\omega,t}+\frac{1}{2}\sigma^2_{\omega,t}} \Rightarrow e^{\mu_{\omega,t}+\frac{1}{2}\sigma^2_{\omega,t}} = 1 \Rightarrow \mu_{\omega,t} + \frac{1}{2}\sigma^2_{\omega,t} = 0 \Rightarrow \mu_{\omega,t} = -\frac{1}{2}\sigma^2_{\omega,t}. \tag{A1}$$

In the computations to obtain the loglinearized version of the model, we use the following equations that are also derived from the properties of the lognormal distribution:

$$\Gamma\left(\varpi_{t+1},\sigma_{\omega,t}\right)=\varpi_{t+1}\left(1-F\left(\varpi_{t+1},\sigma_{\omega,t}\right)\right)+G\left(\varpi_{t+1},\sigma_{\omega,t}\right), \tag{A2}$$

$$\Gamma_{\omega}\left(\varpi_{t+1},\sigma_{\omega,t}\right)=1-F\left(\varpi_{t+1},\sigma_{\omega,t}\right), \tag{A3}$$

$$G\left(\varpi_{t+1},\sigma_{\omega,t}\right)=1-\phi\left(\frac{\frac{1}{2}\sigma_{\omega,t}^{2}-\log\varpi_{t+1}}{\sigma_{\omega,t}}\right), \tag{A4}$$

and

$$G_{\omega}\left(\varpi_{t+1},\sigma_{\omega,t}\right)=\varpi_{t+1}F_{\omega}\left(\varpi_{t+1},\sigma_{\omega,t}\right). \tag{A5}$$

Appendix B

First order conditions

In this section, we include the first order conditions of the optimization problems of the agents of the periphery country. The same equations apply for the core country of the monetary union.

Households

The first order conditions obtained from the representative household's problem are the following:

$$\frac{1}{c_t}=\lambda_t\left(1+\tau_c\right), \tag{B1}$$

$$\lambda_t=\beta E_t\lambda_{t+1}\frac{\left[1+\left(1-\tau_R\right)\left(R_t-1\right)\right]}{\Pi_{t+1}}, \tag{B2}$$

$$\lambda_t=\beta E_t\lambda_{t+1}\frac{R_t^d}{\Pi_{t+1}}, \tag{B3}$$

$$\psi l_t^{\vartheta}=\left(1-\tau_l\right)w_t\lambda_t, \tag{B4}$$

where λ_t is the Lagrange multiplier that represents the marginal value of wealth of households.

Intermediate goods producers

The first order conditions from the intermediate firms' profits maximization problem are:

$$\frac{k_{t-1}}{l_t}=\frac{\alpha}{1-\alpha}\frac{w_t}{r_t}\frac{p_t}{p_{P,t}}, \tag{B5}$$

$$mc_t=\left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{w_t^{1-\alpha}r_t^{\alpha}}{e^{z_t}k_{g,t-1}^{\alpha_g}}\left(\frac{p_t}{p_{P,t}}\right)^{1-\alpha}, \tag{B6}$$

$$\varepsilon f_t^1=(\varepsilon-1)f_t^2, \tag{B7}$$

where

$$f_t^1 = \lambda_t mc_t y_t + \beta\theta E_t \left(\frac{\Pi_{P,t}^{\chi}}{\Pi_{P,t+1}} \right)^{-\varepsilon} f_{t+1}^1, \tag{B8}$$

and

$$f_t^2 = \lambda_t \bar{\Pi}_{P,t} y_t + \beta\theta E_t \left(\frac{\Pi_{P,t}^{\chi}}{\Pi_{P,t+1}} \right)^{1-\varepsilon} f_{t+1}^2 \left(\frac{\bar{\Pi}_{P,t}}{\bar{\Pi}_{P,t+1}} \right). \tag{B9}$$

where, following Fernández Villaverde (2010), f_t^1 and f_t^2 are two auxiliary variables.

Capital goods producers

The first order condition is the following:

$$q_t \left(1 - S\left[\frac{i_t}{i_{t-1}} \right] - S'\left[\frac{i_t}{i_{t-1}} \right] \frac{i_t}{i_{t-1}} \right) + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} q_{t+1} S'\left[\frac{i_{t+1}}{i_t} \right] \left[\frac{i_{t+1}}{i_t} \right]^2 = 1. \tag{B10}$$

Entrepreneurs

The first order conditions are given by

$$\begin{aligned} E_t \frac{R_{t+1}^k}{R_t} \left[1 - \Gamma\left(\varpi_{t+1}, \sigma_{\omega,t} \right) \right] \\ + \xi_t \left\{ \frac{R_{t+1}^k}{R_t} \left[\Gamma\left(\varpi_{t+1}, \sigma_{\omega,t} \right) - \mu G\left(\varpi_{t+1}, \sigma_{\omega,t} \right) \right] \right\} = 0, \end{aligned} \tag{B11}$$

and

$$-\Gamma_\omega\left(\varpi_{t+1}, \sigma_{\omega,t} \right) + \xi_t \left[\Gamma_\omega\left(\varpi_{t+1}, \sigma_{\omega,t} \right) - \mu G\left(\varpi_{t+1}, \sigma_{\omega,t} \right) \right] = 0, \tag{B12}$$

where ξ_t is the Lagrangian multiplier.

After some algebra, we get

$$q_t k_t \frac{p_{P,t}}{p_t} = \left[\frac{\xi_t}{E_t \frac{R_{t+1}^k}{R_t} \left[1 - \Gamma\left(\varpi_{t+1}, \sigma_{\omega,t} \right) \right]} \right] n_t, \tag{B13}$$

where $q_t k_t \frac{p_{P,t}}{p_t}$ are purchases of capital, as explained before, and where $\frac{R_{t+1}^k}{R_t}$ is the external finance premium, inversely related to the net wealth of the entrepreneur.