COMPARING DIFFERENT FEATURES OF A FISCAL STIMULUS IN THE EURO AREA

Caroline Bozou

Jérôme Creel

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CONTACT US

OFCE
10 place de Catalogne | 75014 Paris | France
Tél. +33 1 44 18 54 24
www.ofce.fr

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ABOUT THE AUTHORS

Caroline Bozou, Université Paris 1 Panthéon Sorbonne.
Email Address: caroline.bozou@gmail.com
Jérôme Creel, Sciences Po, OFCE.
Email Address: jerome.creel@sciencespo.fr

ABSTRACT

We build a two-country DSGE model where we distinguish the core from the periphery of a monetary union. First, we highlight the spillovers of fiscal shocks across countries. Then, we evaluate and compare the macroeconomic effects of the European recovery plan NGEU with national plans. In all settings, we distinguish public consumption shocks from public investment ones, and funding via loans or grants. We also generate a post-Covid situation where we add a zero-lower bound and demand shocks and compare the outcomes to the former scenarios. We find that the stimulus is more effective when it is financed by grants, interestingly enough especially for public consumption, that public investment spending has a higher multiplier effect in the long run and that a European fiscal stimulus has always more impact per country than a national stimulus plan. A side-result permits to assess the opportunity cost of accepting loans.

KEYWORDS: Fiscal policy, open economy, euro area, spillovers, DSGE, NGEU, RRF.

JEL: E12, E62, F41, H68.

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Caroline Bozou and Jérôme Creel *

February 8, 2023

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Corresponding author. Email: caroline.bozou@gmail.com

1 Introduction

Will the stimulus measures taken in Europe following the Covid-19 pandemic be enough to achieve a strong recovery and resilience in the euro area? This question was central to the specification of the Next Generation EU (NGEU) and the Recovery and Resilience Facility (RRF) in 2020. It gave rise to a fiscal stimulus mostly targeted towards public investment measures (for a total amount of €750 bn at constant 2018 euros) with a higher share of the funds allocated to Italy and Spain than to Germany and France. RRF also gave rise to a mixture of European loans and grants to fund the stimulus. The mixture limited via loans and facilitated via grants European risk-sharing between the EU Member States. While European loans induced interest and debt repayments by receivers, European grants were backed by future yet-unknown new European resources. Until these new resources emerge, grants are backed by European debt issuances. Information on the early disbursements of RRF showed that 6 Member States had not requested their allocated funds (Bulgaria, Hungary, Ireland, Netherlands, Poland, Sweden), and among the remaining 21 Member States, only 5 had requested their allocated loans (Cyprus, Greece, Italy, Portugal, Romania).

The aim of this paper is to reconsider the rationale of the NGEU stimulus of promoting public investment measures more than public consumption measures, and more in the "periphery" of the euro area than in its "core" [1], with two distinct financing modes: loans and grants. The questions we ask might be summarized as: drawing on the many facets of a fiscal stimulus (public investment vs. public consumption, core vs. periphery, grants vs. loans, European vs. national), what kind of fiscal stimulus is the most effective at boosting the European economy? And which modalities of the stimulus application are the most effective at recovering specifically from Covid-19?

Drawing on a two-country DSGE model, we evaluate the macroeconomic effects of the NGEU recovery plan and compare them with national plans. The model is an extension of the multi-country New Area Wide Model of the euro area (NAWM) designed by the ECB in which we consider two zones (core and periphery) in a monetary union with a common monetary policy and differentiated fiscal policies. We add a fiscal framework à la Leeper et al. (2010) to simulate the gradual impact of public investment on the economy. The model incorporates country-specific risk premia to account for the imperfect substitutability between domestic and foreign bonds in the monetary union. Therefore, the model allows to highlight the trade and financial spillover effects between the two zones. We use two different settings of the model. The first one implements the usual stochastic simulations with the common monetary policy committed to a Taylor rule. In the second one, we rely on an extended path approach to generate a post-Covid situation where we add a zero-lower bound to monetary policy and demand shocks to simulate the Covid-19 shock on the economies[2]. We then compare outcomes in this post-Covid setting

[1] The distinct features between so-called "periphery" and "core" in our modelling framework will be explained later.

[2] The extended path approach has often been used in the literature to model the ZLB (e.g. Christiano et al. (2011)).This method allows to account for non-linearities and for a reasonable

with those arising in the former "normal" setting.

We simulate alternative scenarios in which the fiscal stimulus can be financed either by a European plan based on grants or loans, or by a debt-financed national plan. The fiscal stimulus can take the form of an increase in productive investment or non-productive current expenditure (public consumption). Fiscal stimulus is simulated alternately for the core and for the periphery.

Main results are the following. First, a European fiscal stimulus is more growth-maximising when it is financed by grants, but especially after a shock on public consumption because the rise in taxes to fulfil the government budget constraint can be postponed. Second, public investment spending is preferable though because it generates higher long-run effects. Third, a European stimulus via NGEU is always more growth-maximising than a national stimulus plan, with only one exception. A national plan is more effective at boosting economic activity than a European plan funded by loans when it is led by the periphery since the increase in its risk premium leads to a higher wealth effect for households of the core which increases their consumption and thus the output. Fourth, thanks to these wealth effects, fiscal multipliers are higher after a shock on public investment when it is funded by EU loans rather than grants, until 3 years after the shock. This effect is even strengthened when the economy is in a post-Covid situation: the rise in the demand for loans accelerates the exit from the zero-lower bound situation. Overall, it appears that NGEU grants are more important for funding public consumption than public investment, in contrast with the actual use of NGEU and RRF by EU Member States.

To date, there are only a few contributions on the expected macroeconomic impact of NGEU funds on the euro area. Most of them use multi-country DSGE models. For instance, Bankowski et al. (2021), assess the macroeconomic impact on the euro area of different uses of NGEU using the EAGLE model developed at the ECB. They simulate alternative scenarios reflecting modalities of the NGEU instruments where three uses of NGEU loans and grants are explored: productive public investment, unproductive government spending, and replacing or repaying existing sovereign debt. Hickey et al. (2020) also used the EAGLE model and focus on public investment. They evaluate the National Development Plan proposed by the Government of Ireland in 2018. Another recent application by Pfeiffer et al. (2021) use the QUEST model developed by the European Commission to evaluate the impact of the NGEU package and its spillovers which are found to be non-negligible.

In line with this literature, we also explore the economic spillovers from NGEU fiscal stimulus. We compare the outcomes of fiscal shocks on an aggregate model representing the entire euro area, with the outcomes of similar shocks on either the core or the periphery of the euro area when both have trade and financial interactions.

Meanwhile, we add to the literature in several respects. First, we compare systematically the macroeconomic effects of shocks on public consumption or on public investment. The former may be preferred by governments for its faster impact on demand, whereas the latter may impinge on the supply side at a longer

treatment of expectations (agents are surprised by the shocks at every periods) horizon. Second, while comparing shocks on public consumption and on public investment, we also compare systematically the outcomes of fiscal shocks stemming from NGEU, either funded by loans or grants, with the outcomes of similar shocks funded domestically. In the latter case, we assume that new fiscal measures are funded by domestic debt issuance. In contrast, loan-funded NGEU new measures incur a lower interest rate due to some risk-sharing, whereas grants incur full risk-sharing and no financial cost in the short run. In this respect, we are able to highlight the real value added of NGEU *vis-à-vis* national fiscal plans. Third, we draw on the peculiarity of public consumption in the model to estimate the opportunity cost of raising taxes. In DSGE models used in the literature, shifts in public consumption lead to tax changes to fulfil the government budget constraint[3]. Thus, comparing the outcomes of a public consumption shock either funded by loans (they impinge on the government budget constraint) or by grants (they have no impact on the government budget constraint) approximates the opportunity costs of raising taxes. While the cost might be trivial, evaluating its size is not: households who are not liquidity-constrained (Ricardian households) hold public debts and may benefit from a wealth effect. The latter disappears when spending is funded by grants, hence a trade-off for Ricardian households in their preference for loans or grants. Fourth, we simulate a post-Covid situation and recalculate the respective impacts of NGEU fiscal stimuli on the core and the periphery.

The remainder of the paper is organised as follows. Section 2 presents the theoretical setup. Section 3 presents our simulations. Our impulse response functions (IRF) are obtained in three distinct parts. First, we analyse the responses after a shock on public consumption and a shock on public investment in the whole euro area. We compare the consequences of loans vs. grants for the entire euro area. Second, we evaluate the same shocks in the core or in the periphery and highlight the spillover effects when countries face a risk premium. We also compare a domestic shock with a European shock. To sum up the different simulation results, we compute the fiscal multiplier effects of each different setting. It permits to highlight the conditions under which fiscal policy has most traction on economic growth. Finally, we develop an extended path simulation and assess the impact of NGEU under a ZLB situation after Covid-19.

2 Model description

We use a two-region (or two-country) DSGE model of the Euro Area where international trade is modeled through an extension of the NAWM model [4]. In the

[3]In contrast, shifts in public investment are funded by debt changes. A golden rule of public finances applies.

[4]The first version of the New Area Wide Model was established by Warne et al. (2008), and has been used in many simulation analyses. For instance, Coenen et al. (2008) examine the potential benefits and spillovers of reducing labor-market distortions caused by Euro-area tax structures whereas Cogan et al. (2013) use the model to study the macroeconomic impact of fiscal consolidation. A second version of the NAWM exists under the name of NAWM II (Coenen et al., 2018). This extension integrates the financial sector allowing to account for a real role of financial frictions in the propagation of economic shocks and the presence of shocks originating from the

presentation of the model, we focus on the exposition of the core region as the periphery is characterized symmetrically.

In each region/country, there are three types of agents: households, firms, and a fiscal authority. Both regions/countries are in a monetary union and share a single monetary authority. Households are divided into "unconstrained households" and "liquidity constrained households" which differ with respect to their ability to access financial markets. Unconstrained households are assumed to have access to financial markets so that they hold bonds issued by the government. They also own the firms whose profit are part of their income. Liquidity constrained households on the other hand have no access to financial market and are therefore "hand-to-mouth" . All households consume and supply labor.

As regards firms, the model differentiates between producers of differentiated intermediate goods in monopolistic competition, and a set of two representative firms, which combine (tradable) domestic and imported intermediate goods into two distinct non-tradable final goods, namely private consumption goods and private investment goods. Producers of intermediate goods use labor, private and public capital as input (Leeper et al., 2010) and produce domestic goods and export tradable goods.

The fiscal authorities purchase the domestic good, invest in public capital, issue bonds to refinance their debt and raise taxes. A fiscal rule is assumed to guarantee the stability of public debt over a sufficient long horizon so that the debt-to-GDP ratio does not need to return to the target level at each period. As in Leeper et al. (2010), we introduce the assumption that public investment takes the form of productive public capital, and that it is accumulated through a law of motion including some "time to build".

Finally, the monetary authority follows a Taylor-type interest-rate rule while the core and the periphery face a risk premium with regard to the deviation of the debt-to-GDP ratio from its steady-state value. This baseline case can be enriched when considering the possibility of a zero lower bound (ZLB). In that case, we impose a non negativity constraint to the nominal interest rate, and we simulate the model through extended path tools.

The model, in its simplicity, remains quite tractable and can provide clear insights on the impact of NGEU plans, allowing to clearly identify the interactions between core and periphery countries in the euro area.

2.1 The model

2.1.1 Unconstrained households

Unconstrained households are denoted by i and their utility function writes:

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\epsilon_t^z \ln c_{i,t+k} - \frac{l_{i,t+k}^{1+\eta}}{1+\eta} \right) \tag{1}$$

financial sector.

For the sake of simplicity, we use the non-extended version of the NAWM and leave shocks to the financial sector for further research.

with β^k the discount factor of households, η the inverse of Frish elasticity of work effort and ϵ_t^z is a preference shock that affects consumption and follows an AR(1) process detailed in section 2.4. The utility depends positively on individual consumption $c_{i,t}$ and negatively on labour supply $l_{i,t}$.

Unconstrained households face the following budget constraint:

$$\begin{aligned} & (1+\tau_t^c)\, c_{i,t} + b_{i,t} + I_{g,t}^s \\ = \quad & \left(1-\tau_t^W\right) w_{i,t} l_{i,t} + \psi_t^g \frac{R_{t-1}^{ea}}{P_{c,t}} b_{i,t-1} \end{aligned} \tag{2}$$

where $w_{i,t}$ is the wage. $I_{g,t}^s$ is the investment in public capital stock[5]. τ_t^c, τ_t^W are respectively taxes on consumption and wage and they are assumed to be exogenous and described in section 2.4. $b_{i,t}$ is the portfolio of sovereign bonds held by households. R_t^{ea} is the risk free interest rate, ψ_t^g is the global risk premium attached to the households' portfolio and $\psi_t^g \frac{R_{t-1}^{ea}}{P_{c,t}}$ can be interpreted as the global real return on portfolio of sovereign bonds.

We assume that households hold a portfolio of sovereign securities composed of a proportion b_1 of domestic bonds and $(1-b_1)$ of foreign bonds.

$$b_{i,t} = b_1 b_{h,t} + (1-b_1) b_{h,t}^* \tag{3}$$

For the sake of simplicity, we assume that the linear combination of bond quantities leads to the same linear combination of risk. The global risk premium of the portfolio is therefore an aggregation of domestic and foreign risk premia.

$$\psi_t^g = b_1 \psi_t + (1-b_1)\psi_t^* \tag{4}$$

The optimization problem of unconstrained households with respect to $c_{i,t}$, $b_{i,t}$ and $l_{i,t}$ gives the following first-order conditions:

$$\lambda_{i,t} = \frac{\epsilon_t^z}{c_{i,t}\,(1+\tau_t^c)\, P_{c,t}} \tag{5}$$

$$\lambda_{i,t} = \frac{\beta E_t \lambda_{i,t+1} \psi_t^g R_t^{ea}}{P_{c,t+1}} \tag{6}$$

$$w_{i,t} = \frac{l_{i,t}^{\eta}}{\lambda_{i,t}\,(1-\tau_t^n - \tau_t^w)} \tag{7}$$

where $\lambda_{i,t}$ is the Lagrangian multiplier of unconstrained households optimisation problem. Note that equation 6 represents the uncovered interest parity condition.

[5]In order to model the private co-financing of public investment, we assume that this investment is not the result of optimization, but follows an ad hoc behavioral rule so we model it as a lump sum tax.

2.1.2 Liquidity constrained households

Liquidity constrained households are denoted by j and their utility function writes:

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\epsilon_t^z \ln c_{j,t+k} - \frac{l_{j,t+k}^{1+\eta}}{1+\eta} \right) \tag{8}$$

The utility depends positively on individual consumption $c_{j,t}$ and negatively on labour supply $l_{j,t}$. Liquidity constrained households face the following budget constraint:

$$\left(1+\tau_t^c\right) P_{c,t} c_{j,t} = \left(1-\tau_t^W\right) w_{j,t} l_{j,t} \tag{9}$$

The solution of the optimization problem of these households with respect to $c_{j,t}$ and $l_{j,t}$ gives the following first order conditions:

$$\lambda_{j,t} = \frac{\epsilon_t^z}{c_{j,t}\left(1+\tau_t^c\right) P_{c,t}} \tag{10}$$

$$w_{j,t} = \frac{l_{j,t}^{\eta}}{\lambda_{j,t}\left(1-\tau_t^n-\tau_t^w\right)} \tag{11}$$

where $\lambda_{j,t}$ is the Lagrangian multiplier of liquidity constrained households optimisation problem.

The presence of liquidity constrained households helps capturing Keynesian effect of fiscal policy as the economy is populated by agents for which the Ricardian equivalence does not hold. We anticipate that the effect of fiscal policy will be larger when the share of liquidity constrained households in the economy $(1-\mu)$ is larger.

2.2 Firms

2.2.1 Intermediate firms

Entrepreneurs produce intermediate goods under perfect competition regime. Each domestic intermediate goods firm produces goods y_t that are sold domestically and abroad following a production function close to Leeper et al. (2010):

$$y_t = T_t \left(k_{t-1}^{\alpha} l_{f,t}^{1-\alpha} k_{g,t-1}^{\alpha_g}\right) \tag{12}$$

where k_{t-1} is productive capital rented by capital producer, $l_{f,t}$ is the aggregated labor demand such that $l_{f,t} = l_{i,t}^{\mu} l_{j,t}^{1-\mu}$ with μ the share of unconstrained households in the production function. $k_{g,t-1}$ is the aggregated public capital, α is the share of private capital in the production function and α_g is the elasticity of output with respect to public capital. T_t is a permanent technology shock that follows an AR(1) process detailed in section 2.4.

Entrepreneurs denoted by e, maximize their utility, which depends only on consumption, according to the following objective function:

$$\mathbb{E}_0 \sum_{k=0}^{\infty} \beta_e^k \ln\left(c_{e,t+k}\right), \tag{13}$$

where $c_{e,t}$ denotes entrepreneurs' consumption, and β_e the entrepreneurs' discount factor. Entrepreneurs are assumed to discount the future more heavily than households such that their discount factor β_e is lower than the households ($\beta_e < \beta$).

Entrepreneurs' decisions occur according to the following budget constraint:

$$c_{e,t} + w_{j,t}l_{j,t} + w_{i,t}l_{i,t} + R_{k,t}k_t = \frac{y_t}{x_t} + R_{k,t}\left(1-\delta_k\right)k_{t-1}, \tag{14}$$

where $R_{k,t}$ is the nominal market price of capital and x_t the markup of final over intermediate goods and δ_k is the depreciation rate of capital.

The optimality conditions of the entrepreneurs after maximization of their utility subject to their budget constraint and production function are:

$$\frac{1}{c_{e,t}}R_{k,t} = \beta_e\mathbb{E}_t\left[\frac{1}{c_{e,t+1}}\left(\alpha\frac{y_{t+1}}{x_{t+1}k_t} + R_{k,t+1}\left(1-\delta_k\right)\right)\right] \tag{15}$$

$$w_{i,t} = \frac{\mu\left(1-\alpha\right)}{l_{i,t}}\frac{y_t}{x_t}, \tag{16}$$

$$w_{j,t} = \frac{\left(1-\mu\right)\left(1-\alpha\right)}{l_{j,t}}\frac{y_t}{x_t}. \tag{17}$$

2.2.2 Capital good producer

Capital producers are in a competitive market. Their aim is to produce new capital and to sell it to entrepreneurs at the nominal market price R_k. The profit maximisation of the capital good producers delivers a dynamic equation for the real price of capital similar to Smets and Wouters (2003, 2007).

Following Gerali et al. (2010), capital producers buy an amount I_t of final good at the beginning of each period and the stock of old non-depreciated capital $\left(1-\delta_k\right)k_{t-1}$ from entrepreneurs. Old capital can be converted one to one into new capital. We assume quadratic adjustment costs. Finally, the amount that capital good producers can produce is:

$$k_t = (1-\delta_k)k_{t-1} + \left[1 - \frac{\kappa_k}{2}\left(\frac{\epsilon_t^{qk}i_t}{i_{t-1}} - 1\right)^2\right]I_t \tag{18}$$

where I_t is the investment, κ_k is the adjustment cost of a change in investment and ϵ_t^{qk} is a shock to the efficiency of investment, which follows an AR(1) process, detailed in Section 2.4.

The profit maximization of the capital good producers delivers a dynamic equation for the real price of capital similar to Smets and Wouters (2003):

$$\begin{aligned} 1 &= q_k\left(1 - \frac{\kappa_k}{2}\left(\frac{\epsilon_t^{qk}I_t}{I_{t-1}} - 1\right)^2\right) - \kappa_k\left(\frac{\epsilon_t^{qk}I_t}{I_{t-1}} - 1\right)\left(\frac{\epsilon_t^{qk}I_t}{I_{t-1}}\right) \\ &+\beta_e\left(\frac{c_{e,t+1}}{c_{e,t}}\right)^{-\sigma_{e,t}}R_{k,t+1}\kappa_k\left(\frac{\epsilon_{t+1}^{qk}I_{t+1}}{I_t} - 1\right)\left(\frac{\epsilon_{t+1}^{qk}I_{t+1}}{I_t}\right)^2 \end{aligned} \tag{19}$$

2.2.3 Retailers

To motivate sticky prices, we assume implicit cost of adjusting nominal prices and monopolistic competition at retail level. A continuum of retailers of mass 1, indexed by z buy intermediate goods y_t from entrepreneurs at a wholesale price P_t^w , differentiate them at no cost and sell differentiated goods at a retail price $P_{h,t}(z)$, $P_{x,t}(z)$, $P_{im,t}(z)$.

We assume that domestic and foreign retailers sell their differentiated good in both domestic and foreign markets with the same structure of price such that we get the same pricing equation with subscript h, x and im for each differentiated goods ($h_t(z)$, $EX_t(z)$, $IM_t(z)$)

The price setting behaviour of intermediate good firm follows an adjustment à la Calvo implying that each period, a proportion $(1-\zeta_h)$ of firms receive permission to optimally reset their prices and choose $\widetilde{P}_{h,t}$. Retailers that receive permission to reset prices choose $\widetilde{P}_{h,t}$ that solve the maximization problem taking as given P_t^w and demand of differentiated good $h_t(z)$, $EX_t(z)$, $IM_t(z)$ (demand is given in section 2.2.4)

The FOC obtained from the optimal pricing behavior is:

$$\sum_{k=0}^{\infty} \zeta_h E_t \left[\Lambda_{t+k} \left(\frac{\widetilde{P}_{h,t}}{P_{h,t+k}} - \frac{x}{x_{t+k}} \right) h_{t+k}(z) \right] = 0 \tag{20}$$

where x_t is the markup $(P_{h,t}/P_t^w)$ which in steady state is equal to $x_t = \epsilon/(\epsilon-1)$, with ϵ the elasticity of substitution between intermediate goods.

The aggregate price index $P_{h,t}$ evolves according to:

$$P_{h,t}^{1-\epsilon} = (1-\zeta_h)\widetilde{P}_{h,t}^{1-\epsilon} + \zeta_h (\pi_{h,t-1})^{1-\epsilon} \tag{21}$$

2.2.4 Final good firms

Final good are obtained by aggregating intermediate goods through a CES aggregation tool:

$$h_t = \left(\int_0^1 h_t(z)^{\frac{\epsilon-1}{\epsilon}} dz \right)^{\frac{\epsilon}{\epsilon-1}} \tag{22}$$

The demand equation of differentiated good are determined by choosing the optimal use of differentiated goods minimising the expenditure for the bundles of differentiated goods subject to aggregation constraint:

$$h_t(z) = \left(\frac{P_{h,t}(z)}{P_{h,t}} \right)^{-\epsilon} h_t \tag{23}$$

and aggregate price index are:

$$P_{h,t} = \left(\int_0^1 P_{h,t}(z)^{1-\epsilon} dz \right)^{\frac{1}{1-\epsilon}} \tag{24}$$

Final goods firms combine purchases of the domestically produced intermediate goods with the imported intermediate goods. They combine it into three distinct non tradable goods, namely final consumption good q_c, investment good q_i and public consumption good g. They are characterized symmetrically such that we use the same equation for all final goods modifying the subscript.

The representative firm produces non tradable final private consumption good $q_{c,t}$, combining purchase of a bundle of domestically-produced intermediate goods $h_{c,t}$ and a bundle of foreign imported goods $im_{c,t}$ using a constant return to scale CES technology:

$$q_{c,t} = \left[\nu_{c,t}^{\frac{1}{\mu_c}} (h_{c,t})^{1-\frac{1}{\mu_c}} + (1-\nu_{c,t})^{\frac{1}{\mu_c}} (im_{c,t})^{1-\frac{1}{\mu_c}} \right]^{\frac{\mu_c}{\mu_c-1}} \tag{25}$$

where μ_c denotes the intratemporal elasticity of substitution between the bundles of domestic and foreign intermediate goods and $\nu_{c,t}$ measures the weight of domestic tradable intermediate goods.

The final goods firm chooses a combination of domestic $h_{c,t}$ and imported goods $im_{c,t}$ that minimizes expenditure $P_{h,t}h_{c,t} + P_{im_c,t}im_{c,t}$, subject to technology constraint 25 and taking the input price indices $P_{h,t}$ and $P_{im_c,t}$ as given. Prices evolve according to:

$$P_{c,t} = \left[\nu_{c,t} P_{h,t}^{1-\mu_c} + (1-\nu_{c,t}) P_{im_c,t}^{1-\mu_c} \right]^{\frac{1}{\mu_c-1}} \tag{26}$$

2.2.5 Monetary policy

As in Warne et al. (2008), the common monetary authority sets the nominal interest rate according to the following log-linear Taylor rule:

$$R_t^{EA} = \phi_R R_{t-1}^{EA} + (1-\phi_R) \left[R^{EA} + \phi_\pi \left(P_{c,t}^{EA} - P_c^{EA} \right) + \phi_{gy} \left(y_{gr,t}^{EA} - 1 \right) \right] + \epsilon_{R,t} \tag{27}$$

where $y_{gr,t}^{EA} = \frac{Y_t^{EA}}{Y_{t-1}^{EA}}$ denotes the euro area output growth, $P_{c,t}^{EA}$ is the euro area gross inflation rate and P_c^{EA} is the euro area gross inflation at its steady state value, ϕ_R captures the degree of interest rate smoothing, ϕ_π and ϕ_{gy} are policy coefficients reflecting the weights of inflation and the output gap, respectively and $\epsilon_{R,t}$ is an exogenous monetary policy shock identical for all European countries, following an AR(1) process detailed in section 2.4.

2.2.6 Government

Government expenditures are split between government consumption g_t (supposed constant unless a shock occurs) and investment in public capital $I_{g,t}$. Government expenditures are financed by a set of fiscal instruments allowing to collect taxes on consumption and on labor income. Government expenditures are also financed by debt contracted with households d_t. The government real budget constraint writes:

$$taxes_t + d_t = g_t + I_{g,t} + \frac{\psi_t R_{t-1}}{\pi_{c,t}} d_{t-1} \tag{28}$$

where $taxes_t$ denotes the total tax revenues:

$$taxes_t = \tau_t^C C_t + \left(\tau_t^N + \tau_t^w\right)\left(w_{i,t} l_{i,t} + w_{j,t} l_{j,t}\right) \tag{29}$$

g_t is assumed to be exogenous such that:

$$g_t = g + \nu_t^G \tag{30}$$

with ν_t^G an exogenous shock of current expenditure described in section 2.4

The borrowing rate associated with the issuance of sovereign debt is elastic to the level of current debt. Thus, the risk premium depends on the deviation of the debt-to-GDP ratio from its target:

$$\psi_t = \exp\left(\psi_n\left(d_{t-1} - \overline{d} p_y y\right)\right) \tag{31}$$

where ψ_n is the sensitivity coefficient of the risk premium to public indebtedness and $\overline{d}$ is the steady-state target for the stock of real debt in proportion to GDP (Badarau et al. (2021)).

2.2.7 Fiscal policy

We assume that the government fulfils a fiscal rule that forces the primary structural balance to adjust in order to stabilize the long run debt-to-GDP ratio. The government's primary structural balance (S_{Struct}) is defined as:

$$Sstruc_t = \tau_t^C C + \left(\tau_t^N + \tau_t^w\right)\left(w_i l_i + w_j l_j\right) - g_t - I_g \tag{32}$$

where variables without time subscript relate to their steady state values. Shifts to public investment and public consumption are interpreted as structural shocks to public finances. Meanwhile, we assume, following Le Moigne et al. (2016), that the government is tied to the following golden rule of public finance:

$$Sstruc_t - \left(\left(\frac{\psi_t R_{t-1}}{P_{c,t}} - 1\right) d_{t-1}\right) = \phi_d\left(d_{t-1} - \overline{d} p_y y\right) - \epsilon_t^G \tag{33}$$

where ϕ_d is the sensitivity of lump-sum taxes to debt-to-output ratio and ϵ_t^G is an exogenous shock allowing for a temporary deviation from the fiscal rule.

2.2.8 Public investment

Following Leeper et al. (2010), $I_{g,t}$ stands for the implemented government investment which is different from authorized government investment A_t. Leeper et al.

(2010) assume that government investment turns into public capital through a time-to-build process, such that the authorized government spending is not immediately implemented and productive.

The law of motion for public capital is:

$$k_{g,t} = (1-\delta_g)k_{g,t-1} + A_{t-N} \tag{34}$$

where N is the number of quarters between granting budget authority and completing a project, δ_g the depreciation rate of public capital, and A_{t-N} the authorized government investment (the stock). The law of motion entails that public capital accumulates on a much longer scale of time (N) than private capital because the stock of public capital is useful only once the project is fully completed.

We add another hypothesis of Leeper et al. (2010): spending outlays authorized by the government occur over several periods. Thus, we consider $\{\phi_0, \phi_1, ..., \phi_{N-1}\}$ the spending rates from the date the investment is authorized ($t = 0$) to the period before project completion ($t = N-1$). Thus we have:

$$I_{g,t+1} = \sum_{n=0}^{N-1} \phi_n A_{t-n} \tag{35}$$

with A_t that follows an AR(1) process described in section 2.4 and decided by the government at each period.

Following Le Moigne et al. (2016), we take into account the possibility that private investment will crowd-in the projects. In order to model this, we force part of the Ricardian (unconstrained) agents' savings into public capital stock in the form of a lump-sum tax LS:

$$(1-\mu)LS_t = Lp \times \left(I_t^S - I^{S*}\right) \tag{36}$$

with Lp the amount of the private leverage effect.

This lump-sum tax is taken directly from the Ricardian agents' savings, thus enter their budget constraint as well as the goods' market clearing condition.
It is directed into the public capital stock:

$$k_{g,t} = (1-\delta_g)k_{g,t-1} + A_{t-(N-1)} + Lp \times \left(A_{t-(N-1)} - A^*\right) \tag{37}$$

2.3 Equilibrium and market clearing

Market clearing conditions write:

$$y_t = c_{,t} + I_t + g_t + I_{g,t} + I_{g,t}^s + \frac{(1-s)}{s} EX_t - IM_t \tag{38}$$

$$q_{c,t} = c_t \tag{39}$$

$$q_{i,t} = I_t \tag{40}$$

Aggregation equations are:

$$w_t = (1-\mu)\, w_{j,t} + \mu w_{i,t} \tag{41}$$

$$c_t = (1-\mu)\, c_{j,t} + \mu c_{i,t} \tag{42}$$

$$h_t = h_{c,t} + h_{i,t} + g_t + I_{g,t} + I^s_{g,t} \tag{43}$$

$$im_t = im_{c,t} + im_{i,t} \tag{44}$$

2.4 Stochastic Structure

The structural shocks are assumed to follow a first-order autoregressive functional form such as:

$$X_t = (1-\rho_X)\,\overline{X} + \rho_X X_{t-1} + \eta^X_t, \tag{45}$$

where $X_t \in \left\{\epsilon^z_t, T_t, \tau^c_t, \tau^W_t, \epsilon^G_t, A_t, \nu^G_t\right\}$, $\overline{X}$ is the steady-state value of X_t, $\rho_X \in [0,1[$ is the first-order autoregressive parameter of the shock X_t and the innovation η^X_t is an $i.i.d$ normal error term with zero mean and standard deviation σ_X.

3 Simulating the NGEU plan

We conduct simulations to highlight the specific impact of the NGEU plan. Simulations are conducted in two parts. First, we compare two polar scenarios where the recovery is led only by public consumption or by productive public investment. Second, we try to reproduce the scenarios in the context of a ZLB and after a Covid-related shock.

3.1 How does the NGEU plan works ?

In July 2020, the European Union (EU) adopted an ambitious financing program called Next Generation EU (NGEU). It combines a Recovery and Resilience Facility (RRF), whose first payments were made as early as summer 2021, with other financial mechanisms (React-EU, etc.) as part of the EU's multi-annual budget, providing member states with 1,850 billion (at constant 2018 prices) euros over 7 years. NGEU has some innovative aspects. First, the issuance of a high common debt (750 billion, also in constant 2018 euros, or 5% of EU GDP), which from 2021 to 2026 will finance a vast program of investment and reforms aimed at channelling the recovery within the framework of the EU's long-term objectives (ecological transition, digitalization, social and territorial cohesion); second, the allocation of resources to the Member States according to the needs induced by the pandemic rather than according to the usual allocation keys. The debt will be repaid between 2028 and 2058, *a priori* through additional own resources (like a tax on financial transactions, a carbon border adjustment mechanism, a tax on plastic packaging, a tax on multinationals), otherwise through increases in countries' contributions to the EU budget. NGEU is an unprecedented tool that offers a coordinated response at the level of the euro area to the Covid-19 crisis.

The two pillars of the NGEU program respond to distinct implementation characteristics and objectives. Specifically, it is divided into €358 billion in loans and €392 billion in grants. Loans allow for a reduction in interest charges for States subject to high market interest rates whereas grants will be reimbursed later and reimbursement shared between all EU Member States.This difference in implementation leads to a difference in the expected net gains of the two funding characteristics. In particular, the net gains from the grants are expected to be higher than those from the loans. It remains though that grants commitments are concentrated in 2021 and 2022. However, actual payments are expected later: less than a quarter by 2023, half in 2023 and 2024, the residual beyond. Grants to Member States will thus take time to be actually paid out whereas loans will be delivered more rapidly.

3.2 Calibration

The model is set at quarterly frequency. Parameters are calibrated according to the literature and to historical steady-state ratios. The list of parameters is reported in table 1.

We assume that peripheral countries represent a lower economic weight than core countries. In line with the literature, we set the size of the core countries to $s = 0.65$. The discount factor of households β is calibrated to 0.995 allowing the nominal rate to be close to 2 percent. The inverse of Frish elasticity of work effort η is calibrated to 1.1 in line with the value of Galí (2008). Labor income share of unconstrained households μ is 0.75 such that 25% of households are assumed to be non-Ricardian (or liquidity-constrained). Corsetti et al. (2013) assume that the elasticity of the risk premium to deviation of the public debt to GDP ratio from steady state varies from 0.0005 when the debt level is 60% to 0.0083 when the debt level is 150%. We calibrate φ_n to 0.007 in this interval. Entrepreneurs are assumed to discount the future less heavily than households such that $\beta_e < \beta$.We calibrate β_e to 0.99. This value remains close to the literature.The capital share in the production function α is set at 0.25, a value commonly used in the literature. Depreciation rate of physical capital δ_k is 0.025 corresponding to a 10 percent depreciation rate per year. The adjustment cost on private investment κ_k is 10, in line with the value estimated by Gerali et al. (2010). Following Le Moigne et al. (2016), we calibrate the depreciation rate of public capital δ_g to 0.0125. The elasticity of output with respect to public capital α_g is calibrated to 0.1 and the private leverage L_p to 2.

We assume that core and periphery countries do not share similar steady-state values of the debt-to-GDP ratio. Core countries have a value of 60 percent of GDP ($\overline{d} = 0.6Y^*$) while periphery countries have a ratio of 90 percent of GDP ($\overline{d} = 0.9Y^*$). This assumption thus introduces a deviation from the fiscal rules embedded in the Stability and Growth Pact: it involves that debt targets are country-specific as recently advocated by Martin et al. (2021). The monetary parameters are standard and in line with the literature. On the fiscal side, we set the steady state value of the tax rate on consumption purchases τ_c and labor income τ_w for core and periphery to 0.183 and 0.066 and to 0.25 and 0.22 respectively.

Table 1: Definition of models' parameters.

Parameter	*Description*	*Core/Periphery*
s	Size of core countries	$0.65/0.35$
	Households' parameters	
β	Households' static discount factor	0.995
η	Inverse of Frish elasticity of work effort	1.1
μ	Share of unconstrained households	0.75
φ_n	Debt elasticity to net asset holding	0.007
L_p	Private leverage	2
	Enrepreneurs' parameters	
β_e	Entrepreneurs' static discount factor	0.99
α	Capital share in the production function	0.3
δ_k	Depreciation rate of physical capital	0.025
κ_k	Adjustment cost on private investment	10
	Public sector parameters	
δ_g	Depreciation rate of public capital	0.0125
α_g	Elasticity of output with respect to public capital	0.1
ϕ_d	Sensitivity of lump-sum taxes to debt to output ratio	0.1
$\overline{d}$	Steady-state target for the stock of real debt	$0.6\,Y^*; 0.9Y^*$
	Monetary policy parameters	
ϕ_π	Weight on inflation in the monetary policy rule	2
ϕ_Y	Weight on output gap in the monetary policy rule	0.125
ρ_R	Interest rate smoothing	0.75
$\overline{\pi}$	Steady-state gross inflation rate	1
ϵ	$\epsilon/(\epsilon-1)$ is the markup in the goods market	6
	Fiscal parameters	
τ_c	tax rate on consumption	$0.18; 0.066$
τ_w	tax rate on labor	$0.25; 0.22$

Commercial trade parameters are given by table 2 and are taken from the value estimated by the NAWM model. Regarding final-good production, we calibrate the home bias parameters υ_c and υ_i such that the model replicates the import content of consumption and investment spending, utilizing the input-output tables for the euro-area.

Table 2: Definition of models' parameters.

Parameter	*Description*	*core/periphery*
ζ_h	Proportion of domestic firms that do not reset their prices	0.8
ζ_x	Proportion of foreign firms that do not reset their prices	0.4
μ_c	Elasticity between domestic and foreign consumption goods	1.9
υ_c	Weight of domestic tradable intermediate consumption good	0.91; 0.89
μ_i	Elasticity between domestic and foreign investment goods	1.6
υ_i	Weight of domestic tradable intermediate investment good	0.41; 0.67

3.3 Assessing the impact of NGEU

In order to carry out our analysis, we consider two polar scenarios in which a shock occurs on public consumption on the one hand, or on productive public investment on the other. These two scenarios allow us not only to distinguish the different spending possibilities offered to the Member States but also the incidence of their funding *via* either loans or grants.

In contrast with a shock on public consumption, the public investment shock includes a time to build of 12 periods (4 years) and a private leverage of 2. In both cases, we assume a public spending shock of 1 percent of GDP (on an annual basis)[6], knowing that the NGEU shock should amount to 5 percent of the euro zone's GDP, i.e. 5 times larger than the simulated shock.

We run alternative simulations to differentiate between four structural frameworks. In the first one, the euro zone is aggregated, i.e. we do not consider spillovers. Here, we only differentiate between a shock on public consumption and a shock on public investment. The next three frameworks introduce two zones (core and periphery) with trade interactions. Moreover, in the second framework, there is no European sovereign bond market. Each country issues its own bonds with specific risk premiums, which are elastic to its current debt level. This amounts to considering a national stimulus plan. Then, in the third framework, countries share a common risk premium. This corresponds to a situation where the EU borrows at a risk-free rate and passes on the benefits to the member states which is equivalent to simulating the loans-related part of NGEU. Finally, we introduce the grant-related part of NGEU after switching-off the impact of higher public spending on the budget constraints of the two countries[7].

[6]The shock on public consumption is therefore immediate, whereas it is only gradual (time-to-build property) after a shock on public investment

[7]Grants are therefore introduced as a free-lunch. On the 20-year horizon of the simulations, we assume that European debt issued to fund these grants has no direct spillover (interest charges, new tax levies) on the core and on the periphery

3.3.1 Public consumption shock

Fig.1 presents a public consumption shock financed by borrowing (solid line) or by grants (dashed line), in an aggregate model for the euro area. Fig.2 and Fig.3 present the same shock with spillover effects between the core and the periphery, considering alternately a national (solid line) or a European recovery plan financed by common EU loans (dashed line) or grants (dotted line).

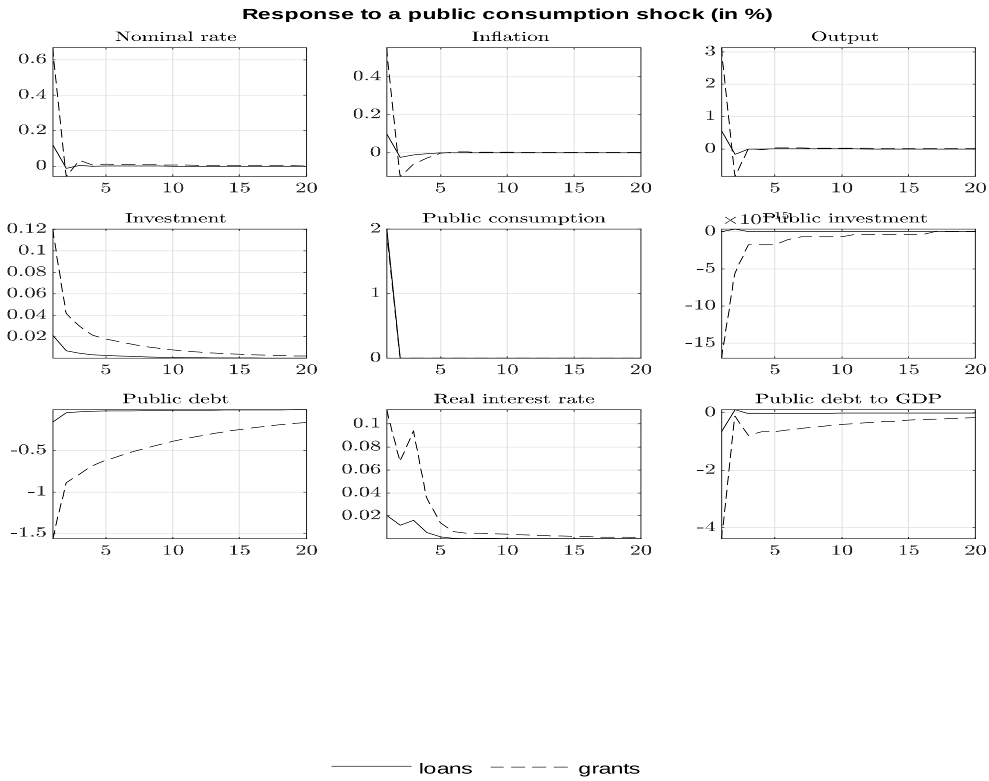

Figure 1: Public consumption shock - aggregate model

In the aggregate model, the increase in public consumption leads to an increase in output relative to its long term equilibrium level. The effect on output is not persistent though while it leads to a decrease in public debt over several periods. The comparison between the different frameworks shows that a recovery financed by grants (dashed line on Fig 1 and dotted line on Fig. 2 and 3) has a larger effect on output than a recovery financed by EU loans (solid line on Fig 1 and dashed line on Fig. 2 and 3) and a moderate effect on the level of public debt. Furthermore, the effect on output is almost similar when the stimulus is financed by NGEU or by national funding (solid line on Fig. 2 and 3). This stems from the assumption that the increase in public consumption is backed by higher taxes and not by debt. Thus, risk premia have little impact on the public consumption shock.

Finally, the spillover effects are significant: taking trade into account increases the initial effect on the output of the country concerned by the stimulus but decreases the aggregate effect of the euro zone (from 3% to 1.5% for grants and from 0.6% to 0.5% for loans). Moreover, the short-run impact on growth of a shock on public consumption is twice as high when it is occurring in the core rather than in

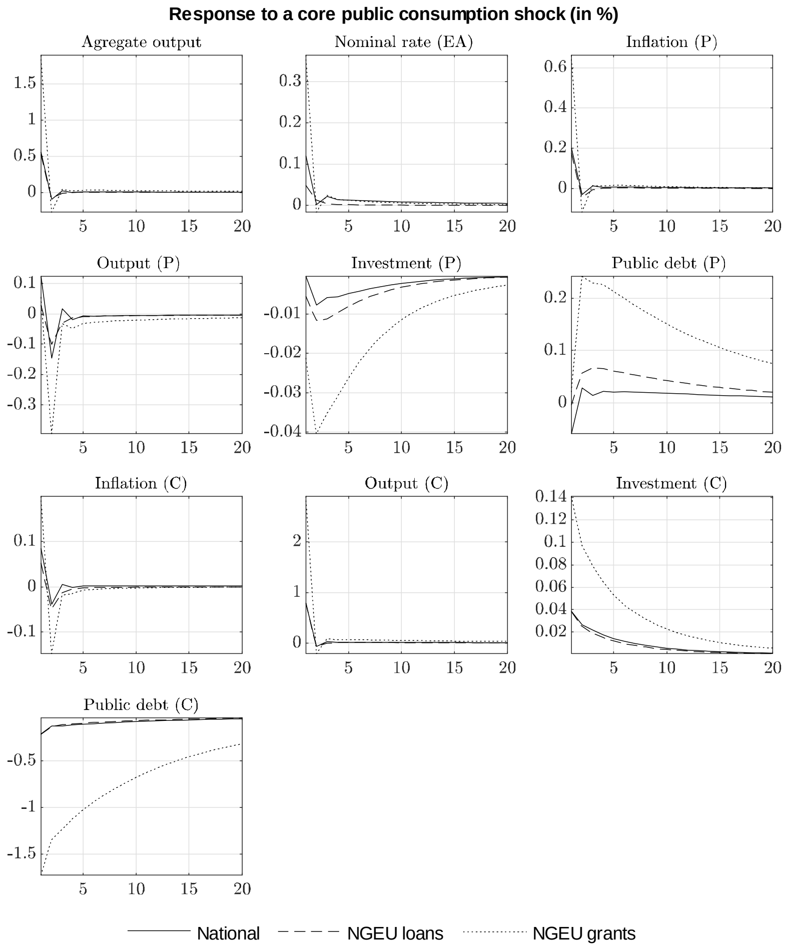

Figure 2: Public consumption shock in the core - model with national stimulus, NGEU loans or NGEU grants

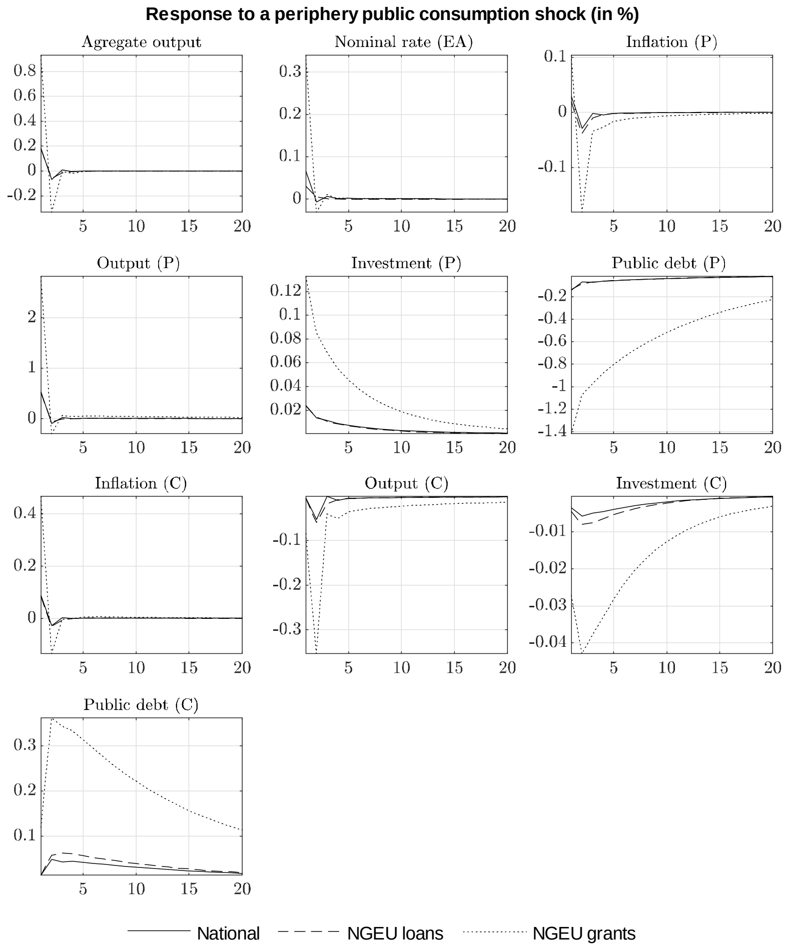

Figure 3: Public consumption shock in the periphery - model with national stimulus, NGEU loans or NGEU grants

the periphery. A shock on the core shows an initial positive effect on the periphery that rapidly vanishes though. In contrast, a shock on the periphery immediately weigh on the core. With funding *via* grants, the lower public debt in the periphery limits the wealth effect in the core.

3.3.2 Public investment shock

Fig.4 presents a public investment shock financed by loans (solid line) or by grants (dashed line), in an aggregate model for the euro area. Fig.5 and Fig.6 present the same shock with spillover effects between core and periphery countries, considering alternately a national (solid line) or European recovery plan financed by common EU loans (dashed line) or grants (dotted line).

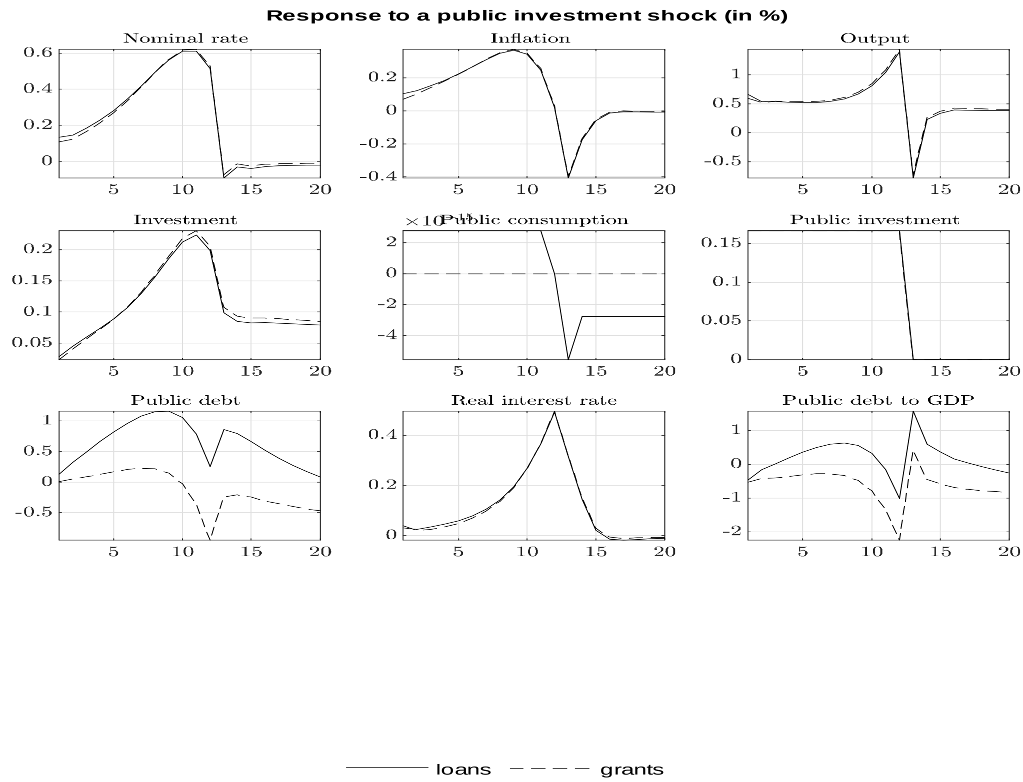

Figure 4: Public investment shock - aggregate model

The effects observed following a public investment shock in the aggregate model are similar to those detailed in the closed-economy framework of Le Moigne et al. (2016). By construction, the investment stimulus plan has persistent effects, unlike the public consumption shock which is absorbed almost instantaneously. The simulation of the public investment shock shows two phases after the shock. The first one corresponds to the time-to-build period of public capital. During this phase, public investment leads to an increase of aggregate demand, up to 0.6% above the long-run equilibrium level, and to an increase of inflation. This releases a reaction of monetary policy that hikes the nominal interest rate. This in turn dampens the expansionary effect of the initial shock. These effects explain the U-shaped GDP reaction function between quarters 1 and 12 following the shock. In the second

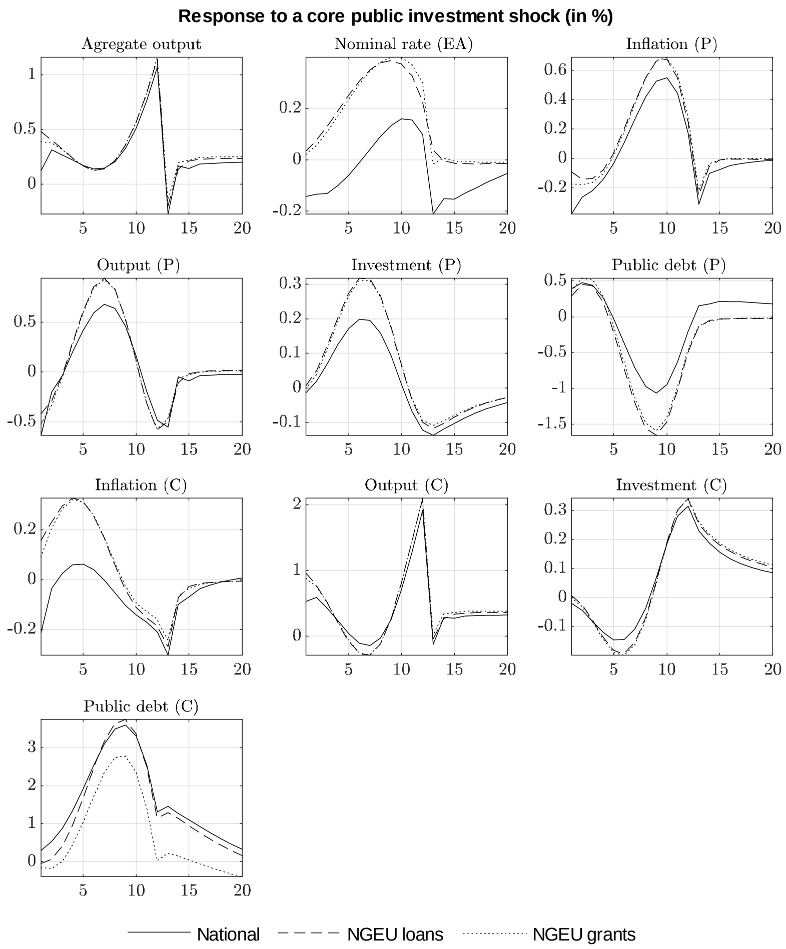

Figure 5: Public investment shock in the core - model with national stimulus, NGEU loans or NGEU grants

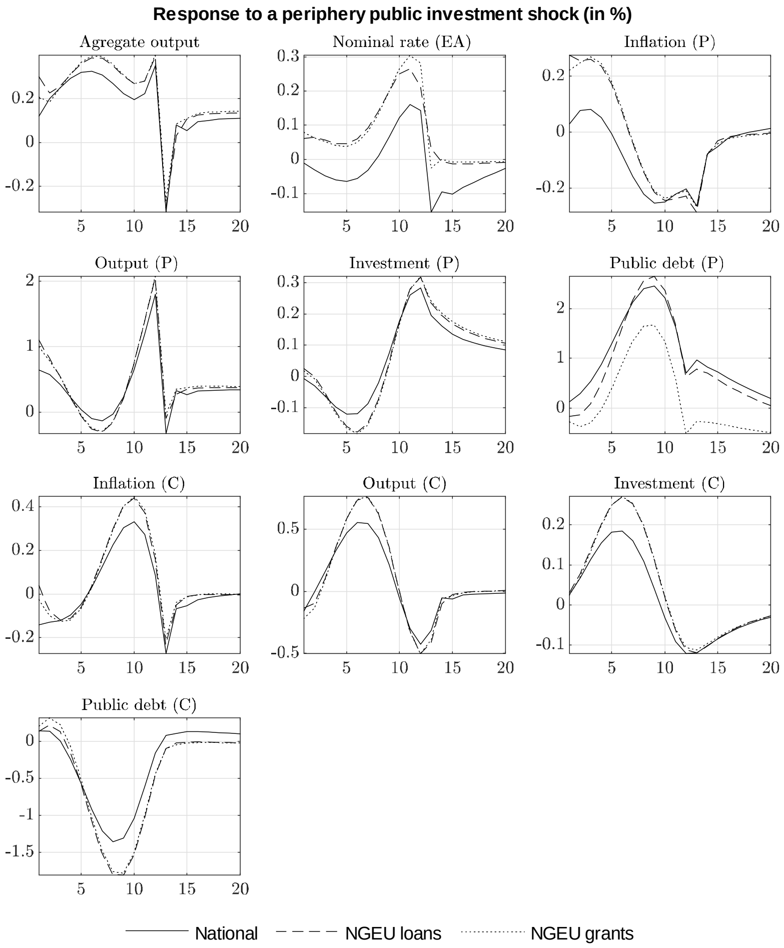

Figure 6: Public investment shock in the periphery - model with national stimulus, NGEU loans or NGEU grants

phase of the shock, the investment effect disappears (explaining the sharp drop at $t = 12$, when GDP shortly becomes negative); however, the new infrastructures become productive, leading to a positive supply effect. Production remains for a very long time above its steady state value, by 0.4%, as long as the new public capital is not completely depreciated. The supply increase also leads to lower inflation, and therefore to a drop in the nominal interest rate.

In contrast with an aggregate shock on public consumption, the funding of an aggregate shock on public investment does not matter much, at least in the first phase. Actually, the dynamic responses of the output are very similar. The main difference lies in the evolution of the public debt to GDP ratio: by construction, it increases under the EU common loan framework whereas it declines under the grant framework. Overall, these results highlight a limited impact of the wealth effect on the economy, except in the second phase where the stimulus *via* grants leads to a rise in output relative to its steady state almost 0.1% greater than the same fiscal package funded by loans. The same difference arises when we take into account trade flows and spillovers (Fig.5 and 6).

The results also show that a national stimulus package will have smaller effects than a European stimulus package funded *via* NGEU (Fig.5 and 6). Since public investment is financed by new issuances of national public debt, risk premia increase and feedback on consumption and investment.

Whether it is implemented by the core or by the periphery, the investment stimulus plan has a positive overall effect on the euro area GDP. However, thanks to spillover effects, a recovery through investment in the periphery has beneficial effects in the short term in the core. Peripheral countries, on the other hand, have to wait longer to see the beneficial effects of an investment stimulus in the core, but then benefit from higher spillovers. This relates to the (realistic) assumption that the degree of openness of the core is smaller than that of the periphery.

3.3.3 The multiplier effects of the stimulus

The results found in the response functions are complemented by a numerical analysis of the multipliers. We calculate the cumulated multipliers of additional GDP for the core and the periphery from the different stimulus packages, whether in the core or in the periphery (tables 3 and 4). Hence, we not only report a proxy for the effectiveness of the fiscal shock on the country where the shock did occur but also its spillovers on the output of the other country/region.

While the multiplier effects might seem very large, they are not unusual in the literature. On impact, the cumulative multiplier effects are consistent with those of Canova and Pappa (2021) for investment shock funded *via* the European Regional Development Fund. After one year, they are close to those found by Bouakez et al. (2017) in the US following the American Recovery and Reinvestment Act (ARRA) of 2009. In the longer run, Ramey (2020) shows multiplier effects close to 9 or even 10 in the literature using New-Keynesian models. Pfeiffer et al. (2021) find lower multiplier effects than those reported in the table below because they include a third region to the model, the rest of the world. Hence, they report higher import leakages from a European fiscal stimulus than we do.

Table 3: Fiscal multipliers by type of stimulus and by type of funding - Shock on the core

	Effect on/after	1 quarter	1 year	3 years	10 years	20 years
Loans						
Public inv. shock	Core	5.79	3.71	3.16	4.33	7.82
	Periphery	-2.51	-0.68	1.28	1	1.19
	EA	2.89	2.18	2.50	3.16	5.50
Public cons. shock	Core	0.39	0.36	0.41	0.43	0.48
	Periphery	0.01	-0.06	-0.08	-0.09	-0.12
	EA	0.26	0.23	0.24	0.25	0.27
Grants						
Public inv. shock	Core	5.30	3.59	3.16	4.46	8.07
	Periphery	-3.13	-0.97	1.16	0.91	1.08
	EA	2.35	2	2.46	3.22	5.63
Public cons. shock	Core	1.45	1.41	1.65	1.80	2.03
	Periphery	0.03	-0.21	-0.3	-0.36	-0.45
	EA	0.95	0.85	0.97	1.05	1.16
National plan						
Public inv. shock	Core	3.18	2.68	2.85	3.85	7.25
	Periphery	-3.81	-1.02	0.79	0.37	0.08
	EA	0.74	1.39	2.13	2.64	4.74
Public cons. shock	Core	0.39	0.37	0.43	0.46	0.52
	Periphery	0.06	-0.01	-0.04	-0.05	0.07
	EA	0.28	0.24	0.27	0.29	0.32

Table 4: Fiscal multipliers by type of stimulus and by type of funding - Shock on the periphery

	Effect on/after	1 quarter	1 year	3 years	10 years	20 years
Loans						
Public inv. shock	Periphery	6.60	4.04	3.17	4.37	7.98
	Core	-0.79	0.34	1.23	0.97	1.07
	EA	1.79	1.64	1.91	2.16	3.49
Public cons. shock	Periphery	0.25	0.23	0.25	0.27	0.30
	Core	-0.01	-0.05	-0.07	-0.08	-0.10
	EA	0.09	0.05	0.05	0.04	0.04
Grants						
Public inv. shock	Periphery	6.00	3.88	3.16	4.51	8.22
	Core	-1.31	0.12	1.17	0.93	1.03
	EA	1.25	1.43	1.87	2.18	3.55
Public cons. shock	Periphery	1.41	1.32	1.51	1.63	1.82
	Core	-0.04	-0.26	-0.37	-0.44	-0.54
	EA	0.47	0.29	0.29	0.29	0.29
National plan						
Public inv. shock	Periphery	3.85	2.80	2.77	3.74	7.27
	Core	-0.95	0.49	0.88	0.61	0.49
	EA	0.73	1.30	1.54	1.71	2.86
Public cons. shock	Periphery	0.26	0.22	0.26	0.28	0.32
	Core	-0.01	-0.04	-0.06	-0.07	-0.09
	EA	0.09	0.06	0.06	0.06	0.05

There are 6 main outcomes stemming from tables that hold similarly for both countries (core and periphery).

First, public investment shocks have a more substantial impact on GDP than public consumption shock. It does appear so on impact, one year after the shock, and in the longer run when the time-to-build process has boosted the productive capacities of the different economies.

Second, after a shock on public investment, the impact on GDP is the highest for the country where the shock occurred if it is funded by EU loans until the "time-to-build" has occurred. After that, beyond 3 years, the impact on GDP is the highest when the fiscal impetus is funded by grants. During the first 3 years after the shock, the wealth effect from Ricardian consumers positively contributes to GDP.

Third, maximum spillovers from the fiscal impetus are achieved 3 years after the shock and when it is funded by EU loans. This confirms that wealth effects matter: EU loans, but not grants, lead to a rise in public debts that in turn generate some wealth effects.

Fourth, the simulations give an appraisal of the *real* advantage of grants vs. loans. Actually, grants permit to escape a rise in taxes to fund the increase in public consumption and limit that of public debt. The opportunity costs of raising taxes after a shock on public consumption can be proxied by the difference between the multiplier effects when the shock is funded *via* grants or loans. For the euro area, it amounts to +0.7 percentage points of GDP after 1 quarter if the shock has hit the core, and to +0.4 pp if it has hit the periphery. It will climb to +0.9 pp after 20 years in the first case, but decrease to +0.25 pp in the second case.

Fifth, public investment multipliers also show that the NGEU program would give GDP more traction in both the short and long run compared to a similar fiscal shock financed by domestic debt. This is due to the effect of risk premia that adjust as a result of the increase in public debt. Despite the wealth effect, the rise in the risk premia and in debt after a domestic shock produces a decline in investment that weighs on aggregate demand. The superiority of a European investment shock on a domestic investment shock shows only one exception: after 1 year, a shock on the periphery has a higher GDP spillover on the core if the shock has been a domestic one. This results from the higher rise of peripheral debt that generates a higher wealth effect in the core, in contrast with a European-funded shock in the periphery. This effect is limited in time, though.

Sixth, NGEU grants are more important for public consumption than for public investment.Comparing cumulative fiscal multipliers after a shock on public consumption shows that they are much higher when spending is funded by grants rather than loans. The choice between loans and grants after a public investment shock is less crucial for cumulative fiscal multipliers are very close.

It must be stressed that the values of the public investment multiplier are sensitive to the level of leverage, set at 2 in the benchmark case (see table 5). This level could well be lower or higher, making the cumulative multiplier effects discussed so far either over- or under-estimated.

Last, fiscal multipliers are also sensitive to the assumption about how productive public capital may be. A lower productivity reduces the fiscal multiplier of public investment in the long run (table 6). Symmetrically, a lower time-to-build period of public investment increases the fiscal multiplier.

Table 5: Fiscal multipliers of public investment financed by loans, by level of leverage

Shock on / Effect on	Public Inv. shock	1 year	3 years	10 years	20 years
Core	$Lp = 4$	7.11	6.17	8.25	14.28
	$Lp = 3$	5.43	4.69	6.33	11.11
	$Lp = 2$	3.71	3.16	4.33	7.82
	$Lp = 1$	2.07	1.73	2.48	4.76
Periphery	$Lp = 4$	7.46	6.14	8.13	14.33
	$Lp = 3$	5.70	4.67	6.24	11.15
	$Lp = 2$	4.04	3.17	4.37	7.98
	$Lp = 1$	2.18	1.73	2.45	4.79

Table 6: Fiscal multipliers of public investment financed by loans, for alternative calibrations

Shock on / Effect on	Public Inv. shock	1 year	3 years	10 years	20 years
Core	$\alpha^g = 0.05$	3.77	3.27	3.82	5.68
Periphery		3.90	3.22	3.72	5.64
Core	$N = 4$	8.45	10.87	13.36	18.45
Periphery		7.25	9.01	11.27	16.01

4 The NGEU under a Zero Lower Bound: a post-Covid illustration

This section simulates the NGEU under the economic conditions that applied after the Covid 19 crisis. In particular, we study the effects of the NGEU programme after a series of shocks that deteriorates output and allows interest rates to move in zero-lower-bound (ZLB) territory.

In that case, we impose to the monetary policy that the nominal interest rate cannot be negative. We modify the Taylor rule with argument max such that:

$$R_t^{EA} = \max\left(\phi_R R_{t-1}^{EA} + (1-\phi_R)\left[R^{EA} + \phi_\pi\left(P_{c,t}^{EA} - P_c^{EA}\right) + \phi_{gy}\left(y_{gr,t}^{EA} - 1\right)\right] + \epsilon_{R,t}; 1\right) \quad (46)$$

Given that the euro area has long been in a liquidity trap situation, we take that context into account in our simulations. In order to model the liquidity trap situation, we apply symmetric negative shocks to the core and the periphery, which seems realistic since the pandemic has affected all the countries of the euro area. The negative demand shocks imply a sharp drop in the rate of time preference. This amounts to lowering the real rate of the economy. This strategy is often used in the

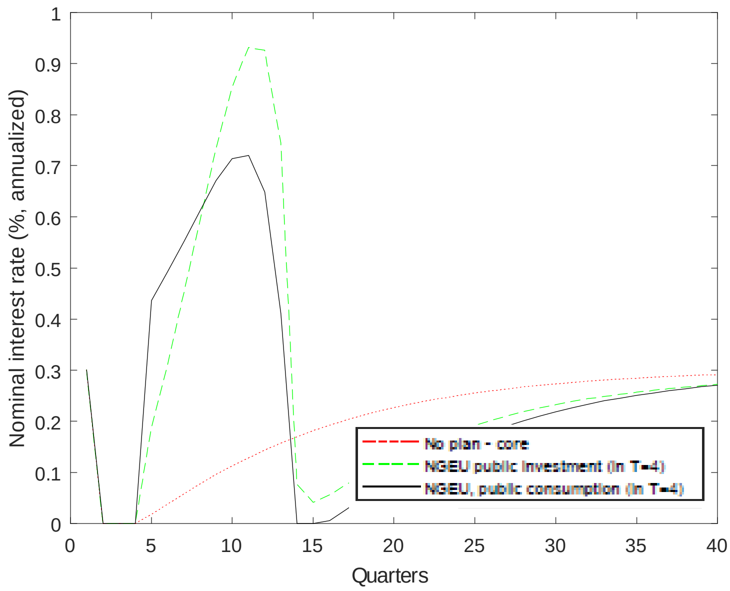

Figure 7: Impact on interest rates of NGEU scenarios in the context of a ZLB - Financing by loans

literature to model the ZLB (Christiano et al., 2011). In our model, we calibrate this shock so as to obtain a ZLB over several quarters.

Finally, we solve the model using the extended path method. This method takes account of non-linearities as well as a reasonable treatment of expectations. The agents are surprised by the shocks at every periods. Extended path simulations allow also to set the size of the shocks as close as possible to the post-Covid situation.

4.1 NGEU, ZLB and loans

We analyse the path of nominal interest rate (Fig.7) and GDP (resp. Fig 8 on core and Fig 9 on periphery) when the economy is plunged into a liquidity trap under three scenarios. In the first scenario (dotted line), there are no fiscal plans (or fiscal reactions to the shocks). The second scenario (dashed line) implies a public investment recovery plan while the third scenario (solid line) is a public consumption recovery plan. In these simulations, we assume that all shocks affect the core and the periphery in the same proportions and we assume that the fiscal plans are financed by loans. The impact of grants is studied later.

The stimulus package, whether it is an increase in consumption or investment, leads to an increase in aggregate demand which contributes to increasing inflation and therefore triggers an intervention from monetary authorities *via* increasing interest rates. The investment-led recovery allows for a more significant and sustainable exit from the ZLB than a consumption-led policy.

Whatever the nature of the European recovery plan (public investment- or consumption-related), its implementation allows the output gap to close fairly quickly in the core countries. However, at the end of the time-to-build period, or once public consumption spending is completed, GDP will fall significantly. In

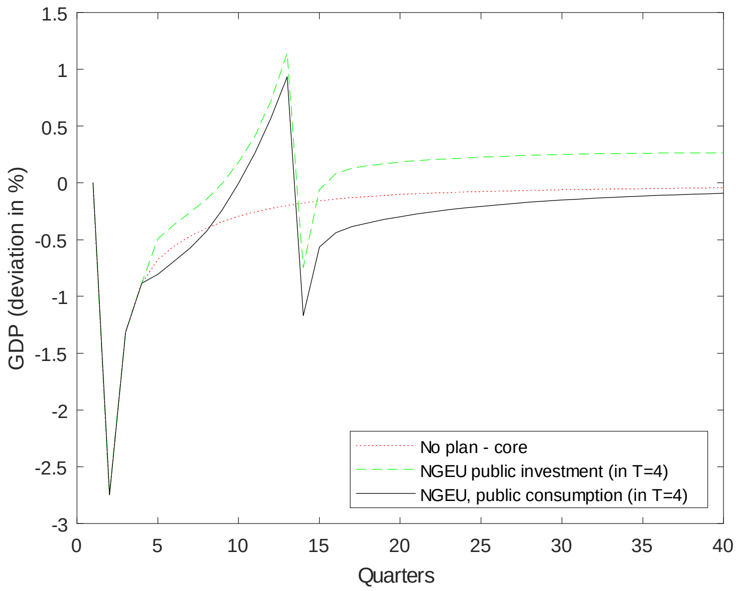

Figure 8: Impact on core GDP of NGEU scenarios in the context of a ZLB - Financing by loans

the long run, GDP remains below its stationary state if the recovery is carried out by public consumption. On the other hand, it is durably above its steady state with a recovery through investment. This latter outcome is consistent with Bouakez et al. (2020).

4.2 NGEU, ZLB and grants

We run the same simulations as in the former subsection but we analyse the path of nominal interest rate (Fig.10) and GDP (resp. Fig 11 on core and Fig 12 on periphery) when the fiscal plans are financed by grants. While the real impacts on the core and the periphery share similar shapes as those reported after EU loans funding, a public consumption shock financed by a grant shows bigger real impacts in the short run that rapidly trigger a rise in the policy rate that thus escapes the ZLB. The reason behind lies in the debt-economy provided by grants that limits recourse to taxes. This illustrates again the opportunity costs of loans vs. grants. In the longer run, a shock on public investment funded by grants has a higher impact on both GDPs, in comparison with a shock on public consumption.

4.3 NGEU and the ZLB: a summary of results

Table 7 summarizes the main outcomes from the simulations of policy shocks under an extended-path approach. For each type of fiscal shock (on public investment or on public consumption) and each type of funding (loans or grants), the table 7 shows the extra-gain of the policy, including cross-spillovers, *vis-ã -vis* no policy at all. First, in most cases, a European-wide reaction to the Covid-like crisis brings the output gap back to its steady-state value. Exception to this occurs when the core

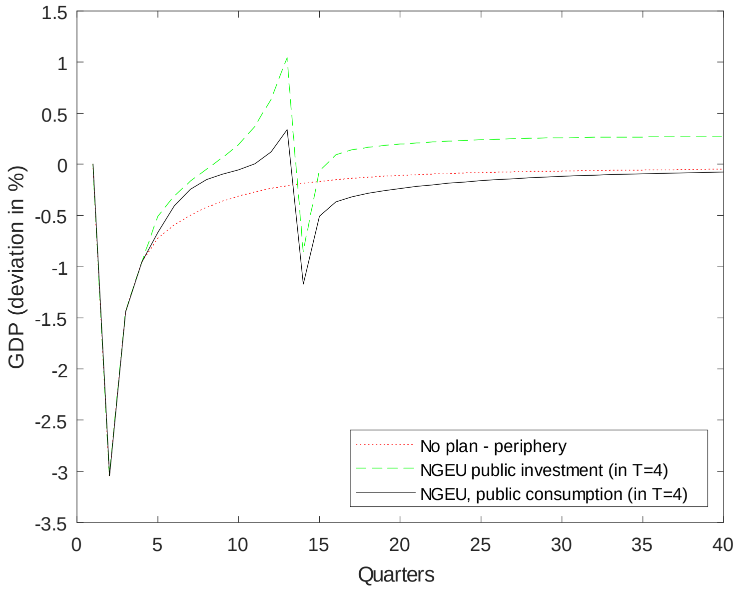

Figure 9: Impact on periphery GDP of NGEU scenarios in the context of a ZLB - Financing by loans

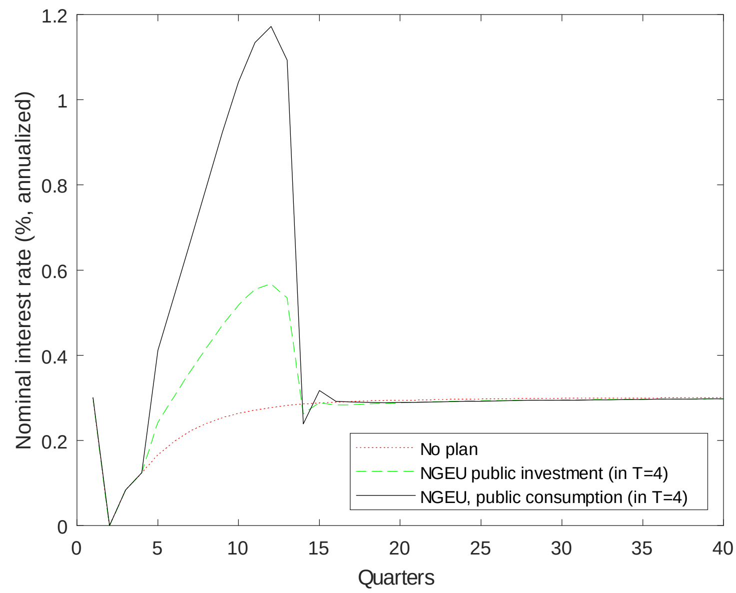

Figure 10: Impact on interest rates of NGEU scenarios in the context of a ZLB - Financing by grants

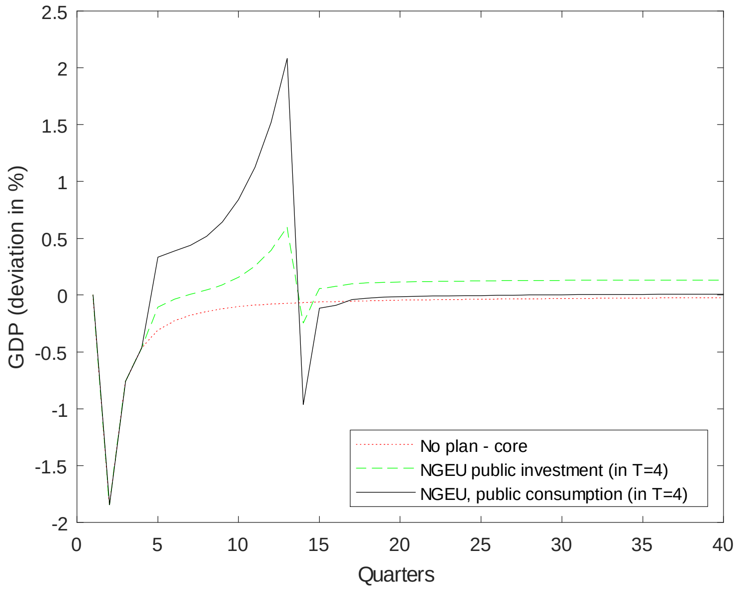

Figure 11: Impact on core GDP of NGEU scenarios in the context of a ZLB - Financing by grants

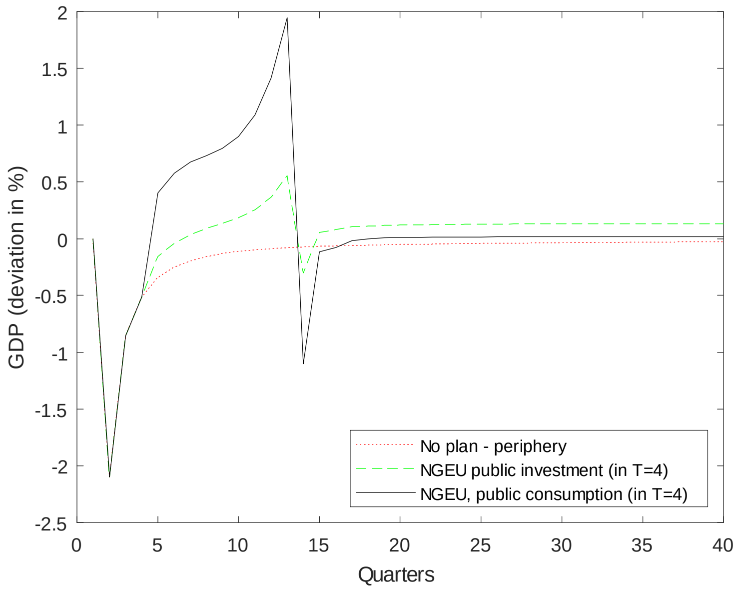

Figure 12: Impact on periphery GDP of NGEU scenarios in the context of a ZLB - Financing by grants

Table 7: Cumulative effect on output of a European-wide fiscal stimulus, in comparison with no fiscal stimulus, in percentage points of GDP

	Effect on	1 year	3 years	10 years	20 years
Loans					
Public inv.plan	Core	0.83	4.35	6.54	12.84
	Periphery	1.2	5.56	7.02	13.48
Public cons.plan	Core	-0.39	0.75	-0.79	-2.27
	Periphery	0.76	0.91	-0.11	-0.98
Grants					
Public inv.plan	Core	0.76	2.78	4.04	7.18
	Periphery	0.87	2.9	2.24	7.48
Public cons.plan	Core	1.38	8.21	8.42	9.04
	Periphery	3.32	8.86	9.31	10.25

and peripheral countries target public consumption expenditures and fund them with EU loans. The early rise in the nominal interest rate coupled with raising taxes slowdowns the pace of the recovery. Second, grants are very favourable until 10 years after the Covid-like crisis if they fund public consumption whose real impact on the economy is more immediate. Third, it takes more than 10 years for a European fiscal stimulus on public investment to get more effects on GDPs than a stimulus on public consumption. This happens if public investment is funded by EU loans: in this situation, the wealth effect brings some traction on economic activity.

5 Conclusion

We have used a DSGE model to evaluate the macroeconomic effects of the NGEU recovery programme. We have compared its related fiscal stimuli with domestically-funded fiscal policies, while taking due account of spillover effects, heterogeneities between European economies, the distinction between public consumption and public investment, and the distinction between loans and grants. We have also added a zero-lower bound to monetary policy and demand shocks to generate a post-Covid macroeconomic situation that we compare to the former scenarios.

We find that a fiscal stimulus is more effective in most cases when it is financed by grants, that public investment spending can be preferable under a long-run perspective and that a European stimulus like NGEU is always more effective than a national stimulus plan. The model also helps shedding light on the opportunity cost of accepting loans rather than grants. This cost is quite limited though. The model finally shows that the choice between grants and loans is much more important when the instrument of fiscal policy is public consumption rather than public investment. Lastly, the economic context of the fiscal stimulus does matter: loans become more important than grants at generating a higher impact of public investment on GDP after the economy has plunged in a ZLB.

All these outcomes are model-consistent and they depend on modelling choices.

The real impact of a public investment shock can vary substantially according to the leverage and to the productive properties associated with public capital (productivity, time-to-build). The wealth effects by patient or Ricardian households may differ in intensity or may be time-varying. Moreover, we assumed that EU loans would be redeemed like public debts, without differed payments on the interests and capital. All these assumptions are finally a matter of empirics that we leave to further research.

Policy implications of the paper might be twofold. First, the paper promotes the full use of the NGEU programme and the RRF as it is shown that a European fiscal stimulus is maximising the real output in contrast with similar policies funded domestically. Second, in the post-Covid situation, the model highlights the economic rationale for making a full use of loans as it accelerates the exit from the ZLB.

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Part I
Appendix

6 Recursive pricing equation

The pricing FOC is given by

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,k} \left(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon - 1} \frac{1}{X_{t+k}} \right) Y_{t+k}^* (z) \right\} = 0 \tag{47}$$

where $X_{t+k} = \frac{P_t}{P_t^w}$.denote the markup of final over intermediate goods. Using the demand function, this is

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,k} \frac{1}{P_{t+k}} \left(\frac{P_t^* (z)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k} \left(P_t^* - \frac{\epsilon}{\epsilon - 1} \frac{P_{t+k}}{X_{t+k}} \right) \right\} = 0 \tag{48}$$

or (by dividing by P_t

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,k} \left(\frac{P_t}{P_{t+k}} \right)^{-\epsilon} \left(\frac{P_t^* (z)}{P_t} \right)^{-\epsilon} Y_{t+k} \frac{P_t}{P_{t+k}} \left(\frac{P_t^*}{P_t} - \frac{\epsilon}{\epsilon - 1} \frac{P_{t+k}}{P_t} \frac{1}{X_{t+k}} \right) \right\} = 0 \tag{49}$$

Now plug in for the stochastic discount factor

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta^p \frac{c_{p,t+k}^{-\sigma_p}}{c_{p,t}^{-\sigma_p}} \left(\frac{P_t}{P_{t+k}} \right)^{1-\epsilon} \left(\frac{P_t^* (z)}{P_t} \right)^{-\epsilon} Y_{t+k} \left(\frac{P_t^*}{P_t} - \frac{\epsilon}{\epsilon - 1} \frac{P_{t+k}}{P_t} \frac{1}{X_{t+k}} \right) \right\} = 0 \tag{50}$$

Multiply by $c_{p,t}^{-\sigma}$

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta^p c_{p,t+k}^{-\sigma_p} \left(\frac{P_t}{P_{t+k}} \right)^{1-\epsilon} \left(\frac{P_t^* (z)}{P_t} \right)^{-\epsilon} Y_{t+k} \left(\frac{P_t^*}{P_t} - \frac{\epsilon}{\epsilon - 1} \frac{P_{t+k}}{P_t} \frac{1}{X_{t+k}} \right) \right\} = 0 \tag{51}$$

Using

$$\pi_t^* = \left(\frac{P_t^* (z)}{P_t} \right) \tag{52}$$

We can write

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta^p c_{p,t+k}^{-\sigma_p} \left(\frac{P_t}{P_{t+k}} \right)^{1-\epsilon} (\pi_t^*)^{-\epsilon} Y_{t+k} \left(\pi_t^* - \frac{\epsilon}{\epsilon - 1} \left(\frac{P_t}{P_{t+k}} \right)^{-1} \frac{1}{X_{t+k}} \right) \right\} = 0 \tag{53}$$

which is equivalant to

$$\begin{array}{c}\sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{1-\epsilon}(\pi_t^*)^{1-\epsilon}Y_{t+k}\right]= \\ \sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{-\epsilon}(\pi_t^*)^{-\epsilon}Y_{t+k}\frac{\epsilon}{\epsilon-1}\frac{1}{X_{t+k}}\right]\end{array} \tag{54}$$

we bring π_t^* to the left

$$\begin{array}{c}\sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{1-\epsilon}(\pi_t^*)Y_{t+k}\right]= \\ \frac{\epsilon}{\epsilon-1}\sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{-\epsilon}Y_{t+k}\frac{1}{X_{t+k}}\right]\end{array} \tag{55}$$

Factoring out, we get

$$\begin{array}{c}\pi_t^*\sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{1-\epsilon}Y_{t+k}\right]= \\ \frac{\epsilon}{\epsilon-1}\sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{-\epsilon}Y_{t+k}\frac{1}{X_{t+k}}\right]\end{array} \tag{56}$$

which define tow auxiliary variables

$$\pi_t^* x_{2,t} = \frac{\epsilon}{\epsilon-1}x_{1,t} \tag{57}$$

where

$$x_{2,t} = \sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{1-\epsilon}Y_{t+k}\right] \tag{58}$$

$$= c_{p,t}^{-\sigma_p}Y_t + \beta^p\theta E_t\pi_{t+1}^{\epsilon-1}x_{2,t+1} \tag{59}$$

and

$$x_1 = \sum_{k=0}^{\infty}\theta^k E_t\left[\beta^p c_{p,t+k}^{-\sigma_p}\left(\frac{P_t}{P_{t+k}}\right)^{-\epsilon}Y_{t+k}\frac{1}{X_{t+k}}\right] \tag{60}$$

$$= c_{p,t}^{-\sigma_p}Y_t\frac{1}{X_t} + \beta^p\theta E_t\pi_{t+1}^{\epsilon}x_{1,t+1} \tag{61}$$

7 Steady state equations

[a actualiser]

$$(1+\tau^c)\,P_cC_i + P_I I + \frac{B_i}{R} + \frac{B_i^*}{R^*} \tag{62}$$

$$= \left(1-\tau^N-\tau^W\right)W_iN_i + (1-\tau^K)R_kK_i + \tau^K\delta P_IK_i + (1-\tau^D)D_i + B_i + SB_i^*$$

$$I = -\delta K \tag{63}$$

$$\lambda_i = \frac{1}{C_i \left(1 + \tau^c\right) P_c} \tag{64}$$

$$P_I = \beta \left[\left(1 - \delta\right) P_I - \left(1 - \tau_t^K\right) R_k - \tau_t^K \delta P_I\right] \tag{65}$$

$$\frac{1}{\beta} = R_t \tag{66}$$

$$\frac{1}{\beta R_t^*} = S \tag{67}$$

$$W_i = \frac{\left(N_i\right)^{\zeta}}{\lambda_i \left(1 - \tau^N - \tau^W\right)} \tag{68}$$

$$\begin{aligned} & \left(1 + \tau^c\right) P_c C_j \\ = & \left(1 - \tau^N - \tau^W\right) W_j L_j + TR_j - T_j \end{aligned} \tag{69}$$

$$\lambda_j = \frac{1}{C_j \left(1 + \tau^c\right) P_c} \tag{70}$$

$$W_j = \frac{\left(L_j\right)^{\zeta}}{\lambda_j \left(1 - \tau^N - \tau^W\right)} \tag{71}$$

$$Y_t = A_t \left(K_f^{\alpha} L_f^{1-\alpha}\right) \tag{72}$$

$$D = Y - R_k K + (1 + \tau^{Wf}) W L \tag{73}$$

$$N = L_i^{\mu} L_j^{1-\mu} \tag{74}$$

$$\alpha \frac{Y}{K} MC = R_k \tag{75}$$

$$\mu \left(1 - \alpha\right) \frac{Y}{L_i} MC = W_i \tag{76}$$

$$\left(1 - \mu\right) \left(1 - \alpha\right) \frac{Y}{L_j} MC = W_j \tag{77}$$

$$MC = \frac{1}{\alpha^{\alpha} (1 - \alpha)^{1-\alpha}} R_k^{\alpha} W_f^{1-\alpha} \tag{78}$$

$$\widetilde{P}_h = \frac{\theta}{\theta - 1} \frac{f_h}{g_h} P_h \tag{79}$$

$$f_h = MC * H + \xi_h \left(\frac{\pi_h}{\pi_h^{\chi_h} \overline{\pi}^{1/4(1-\chi_h)}}\right)^{\theta} f_h \tag{80}$$

$$g_h = P_h H + \xi_h \left(\frac{\pi_h}{\pi_h^{\chi_h} \overline{\pi}^{1/4(1-\chi_h)}} \right)^{\theta - 1} g_h \tag{81}$$

$$P_h^{1-\theta} = (1 - \xi_h) \widetilde{P}_h^{1-\theta} + \xi_h \left(\frac{P_h}{\pi_c} \right)^{1-\theta} * \left(\pi_h^{\chi_h} \overline{\pi}^{1/4(1-\chi_h)} \right)^{1-\theta} \tag{82}$$

$$\pi_h = \pi_c \tag{83}$$

$$\widetilde{P}_x = \frac{\theta}{\theta - 1} \frac{f_x}{g_x} P_x \tag{84}$$

$$f_x = MC * X + \xi_x \left(\frac{\pi_x}{\pi_x^{\chi_x} \overline{\pi}^{1/4(1-\chi_x)}} \right)^{\theta} f_x \tag{85}$$

$$g_h = P_x X + \xi_x \left(\frac{\pi_x}{\pi_x^{\chi_h} \overline{\pi}^{1/4(1-\chi_x)}} \right)^{\theta - 1} g_x \tag{86}$$

$$P_x^{1-\theta} = (1 - \xi_x) \widetilde{P}_x^{1-\theta} + \xi_x \left(\frac{P_x}{\pi_c^{co}} \right)^{1-\theta} * \left(\pi_x^{\chi_x} \overline{\pi}^{1/4(1-\chi_x)} \right)^{1-\theta} \tag{87}$$

$$\pi_h = \pi_{c,t}^{co} \tag{88}$$

$$Q_c = \left[\nu_c^{\frac{1}{\mu_c}} (H_c)^{1-\frac{1}{\mu_c}} + (1 - \nu_c)^{\frac{1}{\mu_c}} (IM_c)^{1-\frac{1}{\mu_c}} \right]^{\frac{\mu_c}{\mu_c - 1}} \tag{89}$$

$$IM_c = \left[\sum_{it} \nu_{im}^{\frac{1}{\mu_{im}}} (IM)^{1-\frac{1}{\mu_c}} \right]^{\frac{\mu_c}{\mu_c - 1}} \tag{90}$$

$$H_c = \nu_c \left(\frac{P_H}{P_c} \right)^{-\mu_c} \tag{91}$$

$$IM_{c,t} = \tag{92}$$

$$P_c = \left[\nu_c P_h^{1-\mu_c} + (1 + \nu_c) P_{c,im}^{1-\mu_c} \right]^{\frac{1}{\mu_c - 1}} \tag{93}$$

$$P_{c,im} = \left[\sum_{it} \nu_{im} (P_{im})^{1-\mu_c} \right]^{\frac{1}{1-\mu_c}} \tag{94}$$

$$Q_i = \left[\nu_i^{\frac{1}{\mu_i}} (H_i)^{1-\frac{1}{\mu_i}} + (1 - \nu_i)^{\frac{1}{\mu_i}} (IM_i)^{1-\frac{1}{\mu_i}} \right]^{\frac{\mu_i}{\mu_i - 1}} \tag{95}$$

$$H_I = \nu_c \left(\frac{P_{H,i}}{P_c} \right)^{-\mu_c} \tag{96}$$

$$P_I = \left[\nu_I P_h^{1-\mu_c} + (1 + \nu_I) P_{I,im}^{1-\mu_c} \right]^{\frac{1}{\mu_c - 1}} \tag{97}$$

$$P_{I,im} = \left[\sum_{it} \nu_{im} (P_{I,im})^{1-\mu_c} \right]^{\frac{1}{1-\mu_c}} \tag{98}$$

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