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ARTICLE

Quantifying spillovers of coordinated investment stimulus in the EU

Philipp Pfeiffer*, Janos Varga, and Jan in 't Veld

Directorate-General Economic and Financial Affairs, European Commission, Rue de la loi 170, 1000, P.O. Box 1049, Brussels, Belgium
*Corresponding author. Email: philipp.pfeiffer@ec.europa.eu

Abstract
In response to the recession brought about by the COVID-19 pandemic, EU-wide macroeconomic policy has launched an unprecedented coordinated fiscal expansion across the EU (Next Generation EU or NGEU), financed by issuing common debt. Given NGEU's nature, it is essential to take fiscal spillovers into consideration when assessing the overall macroeconomic effects of this fiscal expansion. We quantify the effects of the additional public investment for all Member States in a rich macro-model with a trade structure. Our model suggests that, on average, GDP effects are around one-third larger when explicitly accounting for the spillover effects from individual-country measures. For small open economies with smaller NGEU allocations, spillover effects account for the bulk of the GDP impact. We also quantify key transmission channels.

Keywords: International spillovers; public investment; New Keynesian DSGE model; open economy; multiregion; Next Generation EU; NGEU

1. Introduction

The economic fallout of COVID-19 has changed the economic landscape profoundly. In addition to national stabilization measures, EU-wide policy has responded with an unprecedented macroeconomic package that provides significant financial support to reforms and public investment, while also addressing long-term challenges such as climate change and digitalization. This package, Next Generation EU (NGEU), is at the heart of the EU response to the COVID-19 crisis. Financed by issuing common debt, it is worth up to EUR 750 billion (in 2018 prices; 5.4% of EU GDP in 2019), of which EUR 390 billion will be in the form of grants and the rest in the form of loans for the period 2021–2026.[1]

In macroeconomic terms, NGEU is a unique coordinated investment and reform program across the EU. Fiscal spillovers are therefore central to any assessment of NGEU's macro effects. However, economic analysis and policy commentaries often focus on the impact in a given country without considering the beneficial effects of investment plans in the other Member States. The national Recovery and Resilience Plans (RRPs), submitted to the European Commission, only assess the domestic impact of the national plans and exclude cross-border spillover effects.[2] While warranted for the national RRPs, this perspective leaves a gap by overlooking potentially significant spillovers given the strong trade linkages in the EU and the euro area. The need for a large model that captures spillover effects with detailed trade structures also creates methodological challenges. This paper fills this gap by quantifying macroeconomic spillover effects in a rich model distinguishing all 27 Member States and the rest of the world.

Our paper also contributes to the current debate on the macroeconomic effects of the coordinated fiscal stimulus. One line of criticism argued that the disbursements could come too late. For example, Codogno and van den Noord (2021) argue that it would be desirable to design a strong automatic stabilization scheme at the EU level to ensure fast disbursement. Their study also provides a stylized impact assessment of NGEU, showing the package's significant macroeconomic effects. However, by directly assuming the fiscal multipliers based on national NGEU allocations, their study does not take into account fiscal spillovers and other richer transmission mechanisms, which are the focus of our paper. By contrast, Picek (2020) finds large spillover effects, in particular for Member States with smaller grant allocations. However, the static input–output approach does not account for macroeconomic dynamics and second-round effects.[3] In general, the wider debate has focused on the allocation of funds and overlooked both the macroeconomic impacts and the cross-border spillover effects, both of which can be substantial in deeply integrated European economies.

The goal of this paper is to shed light on these issues using a state-of-the-art macro-model. The starting point of our analysis is a workhorse macroeconomic model, the Commission's QUEST model. Designed for fiscal policy analysis, the QUEST framework features key Keynesian ingredients such as liquidity-constrained households and price and wage rigidities commonly incorporated in this class of models. We extend this core model to capture the economic mechanisms and dynamics of public investment in more detail. For example, government investment faces short-run implementation delays, for example, related to contracting time and planning horizons. Together with time-to-build frictions, such delays reduce the short-run multiplier of government investment, as emphasized in Leeper et al. (2010) and Ramey (2020). However, unlike government consumption, public investment can entail a sizeable long-run multiplier by increasing potential output.

We then embed this augmented model into a multicountry structure designed for spillover analysis and featuring rich trade linkages. Our model links each of the 27 EU Member States and the rest of the world, with all elements of the outlined macro-fiscal setup, via trade and financial markets. In particular, a detailed, empirical trade matrix covering trade in both goods and services explicitly accounts for bilateral trade linkages of all regions. Unlike most models, which counterfactually include only trade in final goods, we explicitly model trade in intermediate inputs. This approach helps to account for highly integrated cross-border value chains, an important consideration for fiscal spillovers. As a result, our analysis combines attractive features of a dynamic micro-founded model with detailed cross-border linkages, typically only exploited in static input–output analysis and trade models.[4]

We apply this novel framework to quantify the macroeconomic spillover of NGEU investments, a key aspect of the ongoing policy debate. While necessarily simplifying the full mechanics of NGEU, we distinguish grant and loan allocations for each Member State based on the currently available information (as of June 2021). Also, we fully take into account the increase in EU debt associated with NGEU. A separate EU budget accounts for the new EU-wide debt financed via long-term contributions of the Member States. We consider stylized time profiles and assumptions for the investment program. However, we do not model specific RRPs. Notably, our results do not include reforms or other programs beyond a broad notion of public investment.[5]

Our main conclusion is the importance of large macroeconomic spillovers as a result of the coordinated investment stimulus. Comparing results for a counterfactual unilateral allocation to a single country versus the actual synchronized NGEU allocation quantifies these spillover effects for all Member States. Our results suggest that the EU-wide GDP effects are around one-third larger when explicitly accounting for the spillover effects of foreign-induced demand and exchange-rate dynamics. A simple aggregation of individual effects of the national RRPs would thus substantially underestimate the growth effects of NGEU.

Breaking down GDP effects into direct effects and spillovers reveals strikingly different patterns across Member States. For small open economies with smaller grant allocations, spillover effects account for the bulk of the GDP impact. In some cases, such as Luxembourg and Ireland, positive spillovers explain almost all the impact. However, even in larger economies with deep trade integration, such as Germany, spillovers account for more than half of the GDP effect. By contrast, given their larger NGEU allocations and relatively closed economies, domestic effects typically dominate in countries such as Bulgaria, Croatia, Greece, and Italy. Specifically for Member States outside the euro area and the European Exchange Rate Mechanism (ERM-II), the monetary policy reaction and exchange-rate response matter for the short-run spillovers.

Overall, the stylized simulations show large macroeconomic effects from the coordinated stimulus. Given currently available information on loan uptake, NGEU investment is about 4% of EU GDP.[6] For a 6-year spending scenario, with evenly distributed spending between 2021 and 2026, we find that the level of real GDP in the EU-27 can be more than 1.2% higher in 2026 than foreseen in a no-policy change baseline. Beyond short-run demand for investment goods, public investment can lead to persistent productivity improvements. These supply-side effects imply possibly large long-run multipliers and increased potential output.

The macroeconomic effects of NGEU depend on several factors, including the monetary policy reaction, the productivity-enhancing effects of the investment stimulus, and the speed of disbursement. For example, spillovers are larger when monetary policy keeps nominal rates roughly constant. In this case, the accommodative monetary policy reduces crowding-out effects. By contrast, nominal rates increase more than inflation if monetary policy is active in line with a standard Taylor rule. The corresponding increase in real interest rates then crowds out domestic demand. Assuming low productivity of the investment also reduces the multiplier effects significantly, in particular in the long run, when the supply-side improvements matter most. The persistent supply-side effects also imply that the disbursement speed matters mainly for short-run dynamics but little for the long-run.

The remainder of this paper is structured as follows. Section 2 gives a brief overview of related literature on fiscal spillovers. Section 3 discusses our assumptions on NGEU. Section 4 describes the key modeling relationship while relegating the mathematical details to the online appendix. Section 5 presents our main results. Section 6 concludes.

2. Related literature

The current expansionary fiscal stance due to the COVID-19 pandemic is, in many ways, a reversal of the austerity debate of the last decade. Our analysis contributes to a growing literature on fiscal spillovers in the EU. Input–output models have been used to trace the effects of a final demand shock through multiregional matrices of intra-industry flows of intermediate goods, assuming constant technical coefficients (i.e. the input requirements per unit of output). Picek and Schroeder (2018) review the literature and analyze the spillovers of a German final demand shock using the World Input-Output Database (WIOD). They find that spillovers are relatively small for southern Europe compared to both Germany's direct neighbors and eastern Europe. While acknowledging that the assumption of fixed economic structure and final demand composition would be less credible for larger demand shocks and under behavioral changes, they argue this was not the case over the period 1995–2009. In an exercise more closely related to ours, Picek (2020) applies a static, multiregional input–output model to examine the effects of NGEU and finds large spillover effects, in particular for Member States with smaller grant allocations. In comparison to these static input–output models, our dynamic macro-model accounts for macroeconomic dynamics and second-round effects.

There is also extensive empirical research on fiscal spillovers based on vector autoregressions (VAR). Beetsma and Giuliodori (2011) and Beetsma et al. (2006) estimate fiscal spillovers of a 1% increase in German government spending at between 0.05% of GDP in Greece and 0.4% of GDP in Belgium. Using panel data from OECD (Organisation for Economic Co-operation and Development) countries, Auerbach and Gorodnichenko (2013) find significant fiscal spillovers. The strength of the spillover varies with the state of the economy in the recipient and source countries, with the output multipliers being large in recessions (in both countries). Their estimates also suggest a greater impact than implied simply by the ratio of imports to government spending. Similarly to our paper, Hebous and Zimmermann (2013) find that an area-wide fiscal boost is more effective than a domestic shock. Faccini et al. (2016) report positive international fiscal spillovers from an increase in US government spending on its main trade partners. Their findings also suggest that, for the USA, the international transmission mechanism appears to operate through a financial channel (negative real rates abroad) rather than a trade channel. Dabla-Norris et al. (2017) estimate a panel VAR model that captures cross-country, dynamic interlinkages for 10 euro-area countries. Fiscal spillovers are significant and tend to be larger for countries with close trade and financial links as well as for fiscal shocks originating from larger countries.[7] Ilori et al. (2022) find sizeable positive spillovers of government spending shocks between Germany and other EU economies for most countries in their sample. Alloza et al. (2019) find varied spillover effects for euro-area countries with trade as the central transmission mechanism. Moreover, the spillover growth effects are larger for public investment. Using structural VAR models, Klein and Linnemann (2021) also report sizeable positive spillover effects from US fiscal policy. Their estimates suggest that an exogenous rise in US government spending increases the output and consumption in other G7 economies by about 50% of the US effects, in line with Corsetti and Müller (2013).

A large body of literature has tried to quantify spillovers using macroeconomic models, identifying both a direct demand channel and a competitiveness channel related to inflation differentials and exchange-rate movements.[8] Blanchard et al. (2015) find large spillover effects from a fiscal expansion in core euro-area countries on the peripheral countries if the economy is in a liquidity trap. Corsetti et al. (2010) discuss the key determinants of spillover effects, namely trade openness, trade elasticities, and budgetary assumptions. Devereux et al. (2020) analyze the impact of fiscal spending shocks in a multicountry model with international (sectoral) production networks. Such network structures are central to the international propagation of fiscal shocks. They imply significant upstream and downstream effects of fiscal spending. Without international production networks, international spillovers would be only a third as large.

Spillover effects can also be sizeable in larger models, particularly when nominal interest rates are at the effective lower bound. Using the Commission's QUEST model, in 't Veld (2013) finds that fiscal consolidations in Germany and other core euro-area countries in 2011–2013 substantially reduced GDP growth in southern Member States. Attinasi et al. (2017), on the other hand, emphasize that risk premia and a cross-border confidence channel can mitigate trade spillovers. Elekdag et al. (2022) look at the effects of a 2-year boost to government investment in Germany of 1% of GDP in the IMF's GIMF model. They showed the importance of the monetary policy channel. Under normal conditions, there could be negative spillovers as the monetary stance tightens given higher inflation rates, leading to higher real interest rates across the monetary union. By contrast, higher inflation rates reduce real interest rates at the zero lower bound with constant policy rates, boosting domestic demand in Germany and the rest of the euro area. The associated depreciation further increases net exports. In 't Veld (2017) and Deutsche Bundesbank (2016) report similar results for spillovers of expansionary government investment shocks in Germany with much larger effects at the lower bound. This channel will also play a role in explaining our results. Model simulations in Deutsche Bundesbank (2016) emphasize the importance of the assumed import share. For government consumption, primarily composed of the public sector wage bill, the specific import share is smaller than the average import share of domestic demand, leading to lower "import leakage" and spillovers. By contrast, government investment, as considered in our paper, is likely to have a large import content and hence larger spillovers.

All in all, spillover effects appear to be larger in general equilibrium models and empirical studies focusing on the most recent years. In addition to explicit modeling of trade linkages, the role of monetary policy is crucial for short-run spillovers. Spillovers are smaller when monetary policy reacts to a stimulus by increasing interest rates, which was the standard assumption before the financial crisis. When monetary policy accommodates the stimulus, however, the fall

Table 1. Apportioning across NGEU instruments (for modeling purposes only)

	EUR bn
Grant instruments	396
of which RRF grants	*317*
Loans	166
Total	562

Note: This table reports the assumed grant and loan composition used in the simulations in 2019 prices. Note that this is a highly stylized representation for modeling purposes only; actual sums financed from NGEU are bound to differ. Grant instruments include RRF grants and additional resources such as ReactEU and the Just Transition Fund, which share economic characteristics but follow a different allocation key in the actual implementation, which the simulations only partly reflect.

in the real interest rate can increase spillovers markedly. In a monetary union, an additional effect comes from the accompanying depreciation of the common currency. In input–output tables, these channels would imply changes in the technical coefficients rather than constant coefficients. Finally, two additional aspects are relevant to position our results within this literature. Firstly, we consider a *coordinated* expansion in a rich model. Thus, we expect more significant spillover effects than studies focusing only on bilateral channels and fiscal spending originating in one country alone. Secondly, our focus is on public investment, which, in the medium run, has a larger output multiplier.

3. Next Generation EU

This section discusses our key assumptions on NGEU.

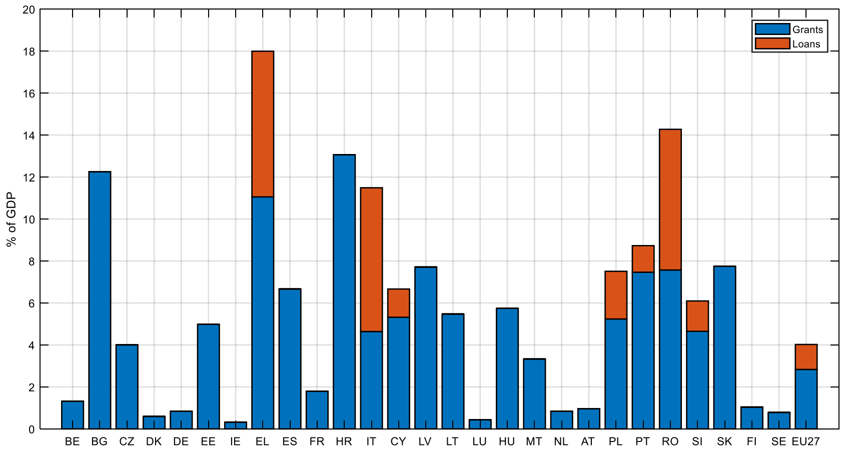
3.1. A historic investment and reform package

NGEU aims to repair the immediate economic and social damage brought about by the COVID-19 pandemic and make Europe fit for current and future challenges. Designed in response to the COVID-19 pandemic, it is a temporary instrument to boost the EU's long-term budget (the multiannual financial framework, 2021–2027).

3.2. A stylized composition and allocation

Modeling NGEU requires several simplifying assumptions. Firstly, we broadly partition the total package into grant and loan instruments, summarized in Table 1, totaling around 4% of EU GDP. NGEU was designed to favor lower-income and vulnerable countries and those particularly hard-hit by the pandemic. A large share of the NGEU package boosts public investment through grants. The allocation of grants across Member States is based on the current Recovery and Resilience Facility (RRF) maximum grant allocation. In total, the simulations assume that EUR 396 bn (in 2019 prices or EUR 421 bn in current prices) will be provided as grants.[9]

On loans, we assume that seven Member States request a total of 166 bn EUR in RRF loans, based on information as of June 2021.[10] Thus, the simulated loan share is significantly below the loan facility's cap at 6.8% of the gross national income of the applicant Member State. Note, however, that the loan amount is expected to increase, because several Member States have indicated that they intend to ask for loans at a later stage. Graph 1 provides an overview.



Graph 1. Overview of assumed allocation.
Note: This graph reports the assumed grant and loan allocation used in the simulations. Note that this is a highly stylized representation for modeling purposes only; actual sums financed from NGEU are bound to differ. Grant instruments include RRF grants and additional resources such as ReactEU and the Just Transition Fund. Two-letter country codes follow EU conventions (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes).

3.3. Financing assumptions

We distinguish between assumptions on grant financing and assumptions on loan financing. For grant financing, the simulations assume that the EU debt is long term (average maturity of around 16 years). The repayment starts at the end of the current multiannual financial framework in 2027 and ends in 2058, following a linear schedule. It is further assumed that all Member States contribute to the EU budget according to their current GDP shares, subtracting from future changes in the GNI shares or new own EU resources. Domestic lump-sum taxes finance these contributions.[11]

The RRF loan repayment by the receiving Member States begins in 2031 and ends in 2050 (following a linear schedule). Interest rates for highly indebted countries are at a more favorable, lower interest rate. Loan repayments by the Member States are also financed via domestic lump-sum taxation.[12]

3.4. Further simplifying assumptions

We make three additional simplifying assumptions. Firstly, the simulations assume an even allocation across the years of NGEU's active operation. We consider a 6-year profile (i.e. 16.67% each year from 2021 to 2026). Online Appendices F and I report the results for a fast scenario, featuring an even allocation across 4 years (2021–2024). The assumed profile is the same for all NGEU components and for all Member States.

Secondly, the simulations assume that the overall NGEU allocation is spent as productive public investment. In national accounts terms, spending on education and training may be classified as consumption, but for modeling purposes, we consider it as productive spending (see next section).[13]

Finally, the simulations assume that Member States use 100% of EU grants for additional public investment, while it is assumed that EU loans are 50% additional. Since the other half of loans finances general government spending, which would take place anyway (and thereby frees up resources), the impact on the national debt is also 50%.[14]

4. A model for fiscal spillover analysis

This section presents a bird's-eye view of key modeling relationships, relegating the detailed mathematical description to Online Appendix B. To quantify fiscal spillover effects, we consider a rich, multiregion, dynamic general equilibrium model, distinguishing all 27 EU Member States and the rest of the world. Our starting point for each region is a macroeconomic workhorse model, the European Commission's QUEST model.[15] The QUEST framework aims to incorporate the features relevant to fiscal policy transmission, as suggested by a large strand of literature. In particular, the model includes price and wage rigidities, liquidity-constrained households, and government debt feedback rules.

Given our focus on public investment, we include detailed public investment dynamics with time-to-build delays and implementation delays along the lines of Leeper et al. (2010). Furthermore, while all regions are isomorphic, we account for key country-specific features, such as trade openness, past public investment rates, and monetary policy setting (i.e. participation in the euro area, the ERM-II, or independent national currencies).

Our main innovation is to embed this workhorse model into a multicountry structure with rich trade features designed for spillover analysis. A detailed trade matrix explicitly accounts for bilateral trade linkages of all regions. The model captures linkages through cross-border value chains by including trade in intermediate inputs for tradable (T) and non-tradable (NT) sectors. To the best of our knowledge, we are the first to consider international fiscal policy in a large-scale model with detailed cross-border production linkages for *all* EU Member States.

4.1. Fiscal policy

4.1.1. Public investment: productivity effects

A central assumption in our study is that public investment is productivity-enhancing, a notion broadly supported by the empirical literature [see Bom and Ligthart (2014); Ramey (2020)], despite identification challenges. Formally, we capture productivity effects by including public capital in the private sector's production process. Higher public capital then increases output for given inputs (private capital and labor). Following Baxter and King (1993), we can write a simplified representation of the private sector production function as:

$$Y_t = N_t^{\alpha} K_t^{1-\alpha} \left(K_t^G\right)^{\alpha_G}, \tag{1}$$

where Y_t, K_t, N_t, α, and K_t^G denote output, private capital, labor, the labor share, and effective public capital, respectively.[16] The output elasticity of public capital, $\alpha_G \geq 0$, drives the medium- and long-run GDP effects in our simulations. We discuss its calibration and sensitivity below.

Besides its supply-side effects, public investment directly enters GDP in the national account expenditure items. Therefore, other things being equal (absent crowding-out effects), higher investment demand drives up output independently of our productivity assumptions. Hence, public investment in the model increases aggregate demand in the short run and aggregate supply in the medium and long run.

4.1.2. Public investment: time-to-build and time-to-spend

Public investment often faces delays in both implementation and construction. For example, projects need to be contracted.[17] New infrastructure projects take time before benefiting their users (e.g. building highways or bridges). Standard approaches [e.g. the seminal contribution of Baxter and King (1993)] often set these issues aside. By contrast, we extend the standard model with time-to-build and time-to-spend delays, along the lines of Leeper et al. (2010).[18]

These features have two main implications. Firstly, government investment is not immediately productive, reflecting time-to-build lags. Thus, in contrast to the standard model, government investment does not translate directly into productivity-enhancing public capital. Instead, with the time-to-build delay, the positive supply-side effects materialize later, reducing the short-run multiplier. Nonetheless, they remain persistent as public capital depreciates only slowly. Formally, effective public capital (entering private sector production) follows the law of motion:

$$K_t^G = \left(1 - \delta^g\right) K_{t-1}^G + A_{t-N}^{IG}, \tag{2}$$

where A_{t-N}^{IG} denotes authorized investment at time $t - N$ and δ^g the depreciation rate of public capital. We model NGEU as shocks to authorized investment.

Secondly, the extended model reflects the fact that not all projects are "shovel-ready" due to planning and contracting time. Such time-to-spend delays (Ramey, 2020) induce lags between authorized investment (appropriations) and implemented government investment following:

$$IG_t = \sum_{n=0}^{N} \psi_n A_{t-n}^{IG}, \tag{3}$$

where the parameters ψ_n, with $n \in \{0, \ldots N\}$, govern the speed of implementation.[19] With this feature, authorized investment only gradually leads to higher (public) investment demand. Thus, unlike in the standard model, the positive, direct demand-side effects also do not unfold immediately.[20]

4.1.3. Government budget

Real government debt (B_t^G) evolves according to:

$$B_t^G = \left(1 + r_{t-1}^g\right) B_{t-1}^G + Exp_t - R_t^G - GR_t^{EU} + CO_t^{EU} + \omega^{EU} r_{t-1}^g B_{t-1}^{G,EU}, \tag{4}$$

where Exp_t and R_t^G summarize the government's expenditure and revenues, respectively.[21] The real interest on bonds (r_{t-1}^g) accounts for a gradual pass-through of policy rates into effective government financing costs associated with the maturity structure of government debt. In the long run, lump-sum taxes stabilize the debt-to-GDP ratio. Receiving a grant (GR_t^{EU}) decreases government debt.[22] By contrast, loans increase debt. These back-to-back loans will be repaid gradually by the beneficiary Member States. We assume that lump-sum contributions (CO_t^{EU}) finance the EU budget in the long run. B_t^G comprises RRF-specific loans and "traditional" government debt. A fiscal expansion financed via RRF loans avoids a widening of interest-rate spreads. By contrast, in a scenario without the favorable RRF loan rate, a fiscal expansion would imply an increase in the government-bond rate. The term $r_{t-1}^g B_{t-1}^{G,\mathrm{EU}}$ captures contributions to interest-rate payments of EU debt, weighted by the country's GDP share in the EU, denoted ω^{EU}. The EU budget aggregates the EU debt issued to finance grants and loans.

4.2. Monetary policy and the zero lower bound

The monetary policy reaction and the exchange rate are important transmission channels of NGEU. Monetary policy in each currency area follows a Taylor rule with a smooth response to inflation and the output gap. Euro-area countries follow a common monetary policy, while we assume an exchange-rate peg (allowing for a small bandwidth) for countries participating in the ERM-II. The remaining Member States implement their independent national monetary policy with a floating exchange rate. We assume that monetary policy is accommodative for six quarters in response to the investment stimulus.[23] Below, we also simulate the model without this assumption to gauge the role of monetary accommodation.

4.3. Household heterogeneity and sticky wages

A rapidly growing literature has emphasized the role of household heterogeneity as important for the transmission of macroeconomic policy (e.g. Kaplan et al. 2018). Given the richness of the multicountry setup, we follow the literature on fiscal policy and include a less involved model of household heterogeneity which nonetheless captures key insights. This formulation distinguishes (optimizing) Ricardian and liquidity-constrained households (rule-of-thumb consumers). The latter households do not participate in financial markets and consume their entire disposable income in every period. Together with imperfect labor and goods markets, this feature implies a higher sensitivity of consumption to income, generating Keynesian effects of fiscal stimulus, in line with empirical evidence [e.g. Galí et al. (2007)].

4.4. International linkages

At the heart of our spillover analysis is a rich trade structure linking individual economies. While adding complexity, this approach captures the transmission of NGEU in the highly integrated EU economy. We add to the existing literature by combining these elements in a large-scale, multicountry model with 28 regions and detailed, cross-border production linkages. We sketch the main features here, relegating mathematical details to Online Appendix B. The model distinguishes T and NT goods and services and explicitly features imported intermediate inputs. The latter capture cross-border value chains and have significant implications for spillovers.[24] We also distinguish a T and a NT sector to capture realistic, real exchange-rate dynamics in response to the public investment shock.

We formalize this setup as follows. Let $Z = C + G + IG$ denote private consumption (C), government consumption (G), and public investment (IG).[25] Preferences of private households and the government for T and NT goods follow CES functions as follows:

$$Z_t = \left(\left(1 - s^T\right)^{1/\sigma_{tnt}} \left(Z_t^{NT}\right)^{\frac{\sigma_{tnt}-1}{\sigma_{tnt}}} + \left(s^T\right)^{1/\sigma_{tnt}} \left(Z_t^T\right)^{\frac{\sigma_{tnt}-1}{\sigma_{tnt}}} \right)^{\sigma_{tnt}/(\sigma_{tnt}-1)}, \tag{5}$$

where Z_t^{NT} is an index of domestic demand across NT varieties, and Z_t^T is a bundle of domestically produced ($Z_t^{T,D}$) and imported T goods ($Z_t^{T,M}$):

$$Z_t^T = \left((1 - s_m)^{1/\sigma_x} \left(Z_t^{T,D}\right)^{\frac{\sigma_x - 1}{\sigma_x}} + s_m{}^{1/\sigma_x} \left(Z_t^{T,M}\right)^{\frac{\sigma_x - 1}{\sigma_x}} \right)^{\frac{\sigma_x}{\sigma_x - 1}}. \tag{6}$$

In equations (5) and (6), σ_{tnt} and σ_x denote the elasticity of substitution between T and NT goods and between the bundles of domestically produced versus imported T goods, respectively. The steady-state shares of T goods in Z_t and imports in Z_t^T are s^T and s_m, respectively. The intermediate inputs in the T and NT sectors are also composites of T and NT analogously to equations (5) and (6), with T being domestically produced or imported. Total imports (M_t) are a CES bundle of bilateral imports from all foreign regions f:

$$M_t = \left(\sum_f \left(s^f\right)^{\frac{1}{\sigma_1}} M_t^{f\,\frac{\sigma_1 - 1}{\sigma_1}} \right)^{\frac{\sigma_1}{\sigma_1 - 1}}, \tag{7}$$

where σ_1 is the elasticity of substitution between imports of different origins M_t^f and s^f is the steady-state share of region f in the domestic economy's imports. Thus, the production structure in each region is linked to intermediate imports from other regions, a key feature in the transmission of fiscal policy. Graphs B.1–B.4 in the online appendix show the detailed (nested) structures for production, final demand, and intermediate demand.

4.5. Real frictions

As typically assumed in larger DSGE models, goods production in our setup also features variable capacity utilization, capital adjustment costs, and labor adjustment costs. In line with estimated model versions [Ratto et al. (2009); Albonico et al. (2019)], these model features help to capture the economy's dynamic behavior.

4.6. Calibration strategy

4.6.1. Main model parameters

Model parameters that characterize the model's steady state are calibrated based on national accounts, fiscal data, and trade data. Steady-state aggregates (like private and public consumption; investment; trade openness; and trade linkages) are calibrated on region-specific data. The steady-state import share in demand for tradables, and the share of intermediates in T and NT sector production are both based on input–output tables from the WIOD database [Timmer et al. (2015)]. The shares of bilateral imports are based on the IMF Direction of Trade Statistics (DOTS) for goods trade and on Eurostat, OECD, and World Trade Organization (WTO) data sources for services. The baseline government debt-to-GDP ratios reflect the average ratios observed over the last decade. Behavioral parameters that govern the dynamic adjustment to shocks are based on earlier estimated QUEST model versions.[26] Parameters for the adjustment of prices and wages, which determine the sensitivity of prices and wages to demand and supply shocks, are informed by evidence of average price and wage adjustment frequencies. Online Appendix C reports further details on the calibration strategy and data sources.

4.6.2. Productivity effects of public investment

A key aspect of our paper is the productivity of public capital. We follow the empirical literature to calibrate its long-run output elasticity (α^G). These studies, however, have found different degrees of productivity, and there is no consensus. A meta-study [Bom and Ligthart (2014)] finds a mean output elasticity of public capital of 0.12. It could be argued that this assumption is an overestimate, as part of the NGEU spending might go to less productive spending such as current rather than capital spending. However, it should be recognized that some spending classified as government consumption, such as education, can have long-run productivity effects similar to—or exceeding—those of infrastructure investment. For robustness, we also consider $\alpha^G = 0.05$ as a low-productivity scenario.[27]

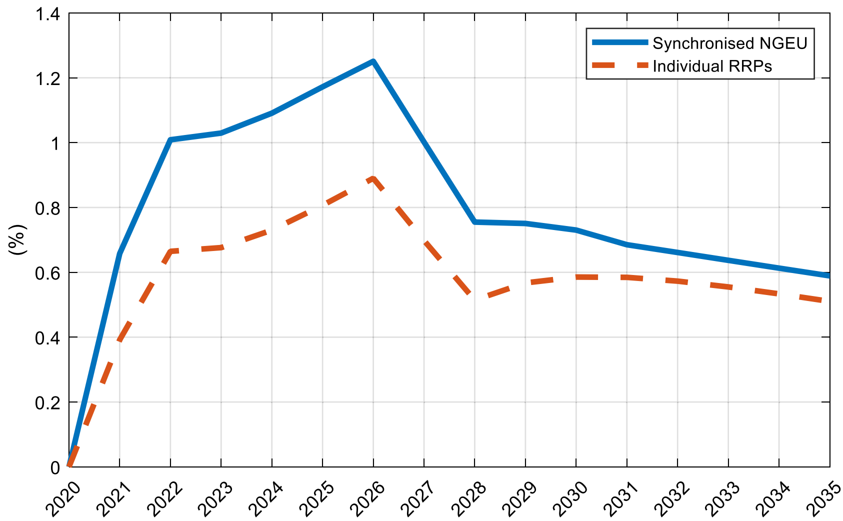
4.6.3. Nonlinear model solution

We solve the full nonlinear model using a Newton–Raphson solution algorithm under perfect foresight. Online Appendix D provides additional details.

5. NGEU macro impact and spillover effects

5.1. Simulation setup to quantify spillover

We quantify spillover effects in three steps. Firstly, we simulate all NGEU investment plans jointly, that is, the actual synchronized plan. Secondly, we run 27 stand-alone simulations based on the (counterfactual) unilateral plans, that is, assuming that only one Member State implements the investment plan at a time. In a final step, we calculate the fiscal GDP spillover for each country as the difference between the GDP effects in the first and the second simulation.



Graph 2. Main simulation results: The role of spillovers on EU-27 GDP.
Note: This graph reports the level of real GDP in percentage deviation from a no-policy change (no-NGEU) baseline. Blue lines show simulation results from a simultaneous investment stimulus (NGEU, 6-year implementation). Orange dashed lines display a synthetic EU-wide GDP (weighted average) obtained by aggregating 27 stand-alone simulations with unilateral stimulus in each country (6-year implementation). All values are yearly averages of the quarterly series.

5.2. *EU-wide results: large spillovers*

NGEU's macroeconomic spillovers are significant. Graph 2 shows that the EU-wide GDP effects are around one-third larger when explicitly accounting for spillover effects. Real GDP in the EU-27 is estimated to be more than 1.2% higher in 2026 compared to a no-policy change baseline (blue lines and right panel). Despite the amplification during the zero-lower-bound period, the time-to-build and time-to-spend delays imply that the output effects unfold gradually. The peak effects materialize at the end of 2026 (due to spending delays, a fraction of public investment continues in the following year). A faster implementation implies larger peak-GDP effects, while the long-term effect (2035) is nearly identical.

By contrast, ignoring positive spillovers reduces the macro impact significantly. We can construct a synthetic EU GDP by aggregating the 27 stand-alone simulations of the unilateral plans (orange dashed lines). Excluding spillover effects in this way, we find GDP effects of around 0.8%–0.9%. Thus, simply aggregating the individual effects of the national RRPs would substantially underestimate the overall growth effects of NGEU.

The level of real GDP remains persistently high even after the disbursement periods: the higher stock of public capital raises the marginal productivity of private production factors under the assumption of productive government investment. As a result of this productivity boost, sizeable medium-run gains in real wages accompany the rise in real GDP.

5.3. *Inspecting the mechanism*

5.3.1. Domestic effects

We can distinguish between domestic demand effects and domestic supply effects. On the supply side, public investment improves domestic productivity with a time-to-build lag (see above). As discussed in Ramey (2020) and illustrated in Online Appendix E, long-run multipliers are higher if the economy starts with a low level of public capital. At the same time, public investment enters GDP in the national account expenditure items as authorized investment gradually increases implemented investment (time-to-spend delays). Thus, other things being equal (absent

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crowding-out effects), higher investment demand drives up output independently of assumptions on productivity. The investment channel is central to the output multiplier. Depending on the persistence of government spending, this channel dampens or amplifies the output multiplier [Dupaigne and Fève (2016)], and more persistent spending shocks can crowd in private investment. Boehm (2020) finds impact multipliers of government investment to be small or close to zero for short-lived shocks due to the crowding-out of private investment, but the multiplier to be greater after long-lived shocks, as is the case in our simulations. The presence of liquidity-constrained households also raises the short-run multiplier. In addition, under accommodative monetary policy (see below), the stimulus reduces the real interest rate and crowds-in private investment [Woodford (2011); Christiano et al. (2011)]. In sum, public investment in the model increases aggregate demand in the short run and aggregate supply in the medium and long run.

5.3.2. Spillover

Two main channels contribute to the large spillovers: direct-trade effects and exchange-rate effects. Firstly, the increase in domestic activity and import demand is the most direct source of positive GDP spillovers. With trade in intermediate inputs, the positive spillover to the import demand and foreign GDP relates to imports of final goods and intermediate inputs into domestic production. This spillover effect will particularly benefit export-intensive countries because of the rising demand from trading partners. In the short run, the lower relative price of foreign-produced goods also shifts demand partially to foreign exports. Importantly, third countries transmit these spillover effects further: the additional production of export goods requires imported intermediate goods from other sources. These channels are more powerful for higher fiscal multipliers because of the stronger output response. Furthermore, in the medium run, the positive supply-side effects of the government investment shock lead to a depreciation of the real effective exchange rate, that is, European export prices increase less than the prices of foreign goods and services. EU exports therefore increase.

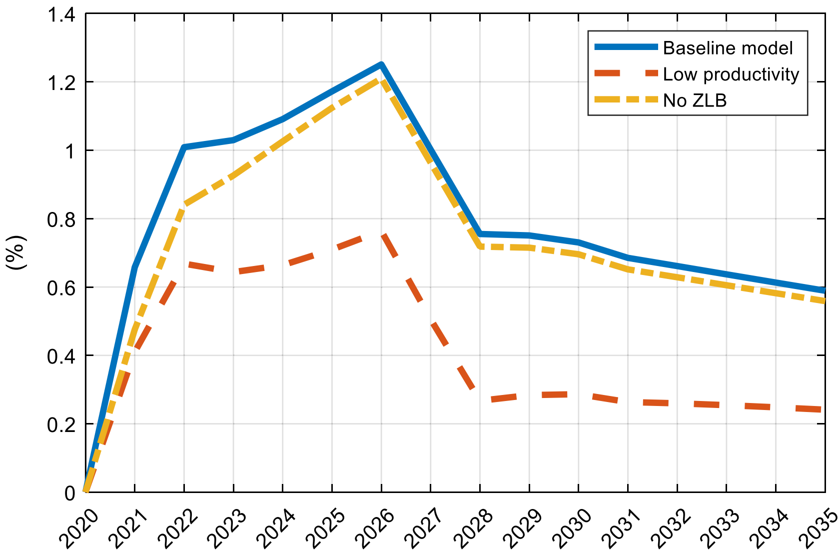
Secondly, there is an additional (nominal) exchange-rate effect. At the effective lower bound, with accommodative monetary policy, relatively lower real interest rates imply (other things being equal) a euro depreciation, that is, prices of domestic goods increase less than prices of foreign goods. The exchange-rate movement then supports exports. Absent exchange-rate policies, this positive short-run spillover effect is lacking or even reversed for non-euro-area Member States, which do not participate in ERM-II.

5.3.3. Effective lower bound and accommodative monetary policy

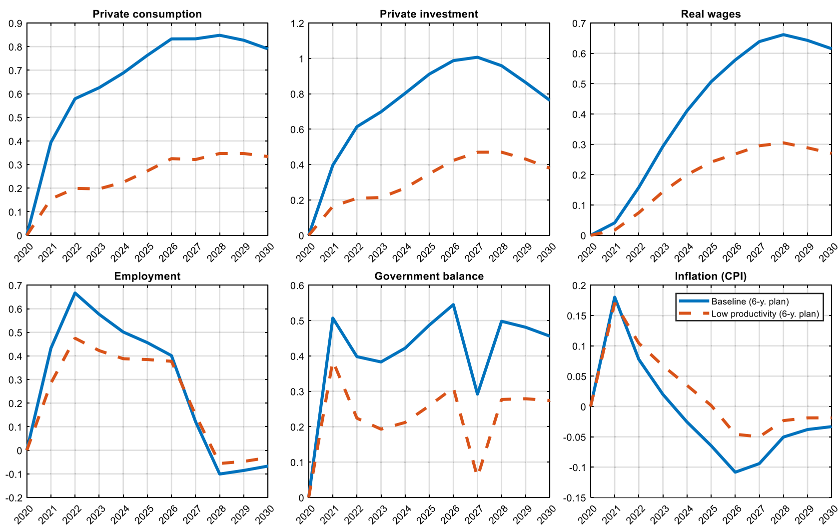
Graph 3 further illustrates the effect of monetary policy operating at the effective lower bound. Our main simulations assume that central banks will (partially) accommodate the expansion. Therefore, without a strong increase in the policy rate and the real interest rate (and given positive employment effects), private consumption and investment expand. By contrast, the short-run GDP effects of government investment are smaller outside the effective lower bound. However, under both monetary policy assumptions, higher government investment crowds in productive private investment in the medium term, because public capital (infrastructure) raises the productivity of the private capital stock, which explains the persistent output gains.

5.3.4. Labor markets

The model simulations suggest a sizeable short-run increase in employment and persistent gains in real wages (Graph 4). The positive employment effect stems from stronger domestic demand. Over time, as productivity increases, the (percentage) increase in employment is smaller than the percentage increase in GDP. Also, for a public investment shock alone (without accompanying labor market reforms), the employment effects are relatively short-lived. By contrast, real wages



Graph 3. Inspecting the mechanism: EU-27 GDP.
Note: This graph reports the level of real GDP in percentage deviation from a no-policy change baseline based on a 6-year profile. Blue lines show simulation results from the baseline model (NGEU). Yellow (dashed-dotted) lines display simulations without an effective lower-bound (ZLB) constraint. Orange (dashed) lines display a low-productivity scenario, setting the output elasticity of public capital (α^G) to 0.05.



Graph 4. Macroeconomic transmission.
Note: This graph reports the government balance (in % of GDP) and inflation in percentage points deviation from a no-policy change baseline. All other variables are expressed in percentage deviation from baseline. All results refer to simulation results from the baseline model (NGEU), assuming a 6-year implementation. Orange lines (dashed) display the low-productivity scenario.

reflect the improved labor market and supply-side conditions: in the medium run, real wages increase substantially compared to the baseline because of higher productivity. Notably, the rise in real wages persists after the governments discontinue direct stimulus packages, while employment levels revert to the baseline.[28] However, the simulations presented in this paper only consider a public investment shock and not the reform measures included in national RRPs which have the

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potential to strengthen productivity growth. By contrast, reforms targeting labor markets can lead to large increases in employment in the medium and long run [Varga and in 't Veld (2014)].

5.3.5. Fiscal position and inflation

The spending boost raises inflation, but this is short-lived. While the initial demand stimulus implies (all other things being equal) a positive output gap, this gap gradually closes again as, following the public investment stimulus, potential output catches up with demand.[29] Governments' fiscal positions improve as the growth stimulus raises tax receipts and reduces the need for financial support for the unemployed. These effects reduce the national debt ratios over a longer horizon.[30] The model accounts for EU-wide debt associated with NGEU but does not incorporate the interinstitutional agreement that new, "own resources" (i.e. EU own revenue sources) will repay this debt. The debt dynamics also depend on the assumed financing of the repayments for RRF loans and grants. We assume that a separate EU budget accounts for the new EU-wide debt. This budget is financed via long-term contributions by the Member States between 2027 and 2058 (according to GNI shares). For Member States requesting RRF loans, the assumed repayment via lump-sum contributions implies an improvement of the primary balance with respect to the baseline over that period, in particular given our assumptions in additionality. Online Appendix G shows the assumed grants, loan receipts, repayments, and additional results per Member State.[31]

5.4. Cumulative multipliers and long-run effects

Turning to the medium and long run, we find that *cumulative* multipliers can be sizeable when government capital is productive. We define cumulative multipliers as the ratio of the additional GDP to the fiscal stimulus.[32] Compared to government consumption, public investment can achieve a sizeable long-run effect by raising long-term productivity. The cumulative multipliers, reported in Table 2 and Graph 5, are in the lower range of the multipliers reported in Ramey (2020, p. 54). For a closed economy (based on a US calibration and a New Keynesian setting), she finds undiscounted long-run multipliers for government investment between 2.9 and 9.8, depending on the assumed productivity of government investment and the initial stock of public capital.[33] The counterfactual stand-alone simulations also show that excluding spillovers considerably reduces the long-run multiplier.

Graph 5 illustrates that the dynamic, medium-run, and long-run GDP effects depend crucially on the assumed output elasticity of public capital. To see this, we show the cumulative multipliers for the baseline model (blue bars) and the low-productivity scenario (red bars), where the output elasticity of public capital is significantly lower.[34] For the more optimistic calibrations, the level of real GDP remains substantially higher even after the implementation period: the higher stock of public capital persistently raises the marginal productivity of private production factors. While sizeable growth effects remain even under more pessimistic assumptions, the changes across assumptions are noteworthy.

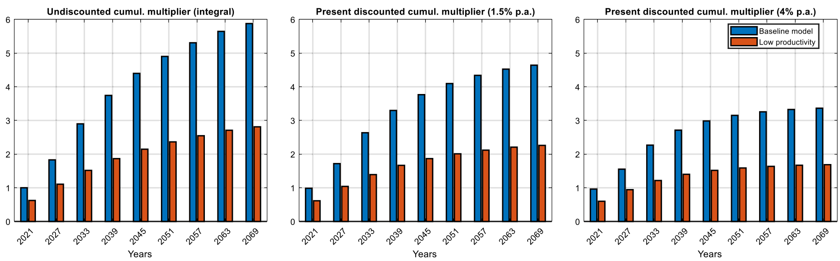
5.5. A closer look at country-specific effects

Even Member States that receive a small allocation of the fund benefit significantly from spillovers from other countries' RRPs. Indeed, in particular for open economies with smaller grant allocations, spillover effects account for the bulk of the GDP impact. In some cases of very small allocations, for example, Luxembourg and Ireland, positive spillovers explain most of the total impact.

Table 2. Illustrative comparison of long-run multipliers (EU-wide)

	This paper		
	Incl. spillover	Counterfactual no spillover (unilateral)	Ramey (2020), New Keynesian model
Government consumption	–		0.9
Government investment (high productivity, undiscounted)	6.5	4.8	4.9–9.8
Government investment (low productivity, undiscounted)	3.1	2.5	2.9–5.4
Government investment (low productivity, discounted)	1.7	1.3	1.7–3.2

Note: This table compares the long-run multipliers of our study with those reported in Ramey (2020, p. 54, New Keynesian model). Our high- and low-productivity settings correspond to $\alpha^G = 0.12$ and $\alpha^G = 0.05$, respectively. In the last row, we apply the same discount factor as Ramey (4% p.a.). Graph 5 shows dynamic results for a lower discount rate (closer to currently observed real interest rates). Multipliers correspond to the ratio of the integrals of the GDP gains and the NGEU funds. We report results including spillovers and a counterfactual synthetic EU aggregate based on the unilateral simulations (no spillovers), as outlined in Section 5.1.

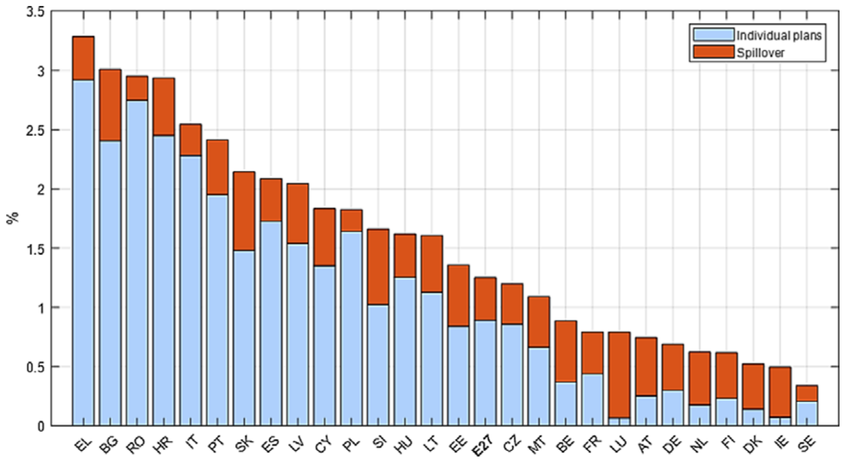


Graph 5. Dynamic cumulative multipliers (including spillover effects).
Note: This graph reports the cumulative GDP multipliers. The multipliers are defined as the ratio of the integrals of the impulse responses of output and the NGEU funds. Blue bars show simulation results from the baseline model (NGEU). Red bars display simulations for a low-productivity scenario. All simulations include spillover effects and refer to a 6-year profile. The left panel shows the undiscounted multiplier, while the middle and right panel display discounted multipliers using a real interest rate of 1.5% (p.a.) and 4% [p.a., as in Ramey (2020)], respectively.

Graph 6 displays the peak-GDP effect for all countries, showing that NGEU strongly supports convergence. Given the allocation key, the Member States with below-average levels of GDP per capita are estimated to experience the largest boost to GDP levels. For a 6-year stimulus and a high-productivity calibration, the increase in output reaches more than 3.2% in Greece; around 3% in Bulgaria, Croatia, and Romania; and around 2.5% in Italy and Portugal. For these countries, the GDP spillover is smaller because their trade partners receive smaller allocations and the economies tend to be less integrated in production chains and trade. The peak effects are larger for the 4-year NGEU scenario but smaller for the low-productivity scenario (see Online Appendix I).

Especially for Member States outside the euro area, the monetary policy reaction matters for the short-run spillovers. There can be a negative short-run spillover for those countries due to the national currency appreciation (although the total GDP effects remain positive). However, this exchange-rate effect is temporary and becomes positive in the second or third year of NGEU. Additional simulations (reported in Online Appendix H) show that if monetary policy in these Member States partially targets the euro exchange rate, NGEU spillover becomes positive immediately.

Table 3 shows spillover effects in the peak year, that is, the sixth year in the 6-year profile, for all (counterfactual) unilateral plans and for all Member States. This table highlights the importance of the relative NGEU allocations and bilateral trade linkages for spillovers (see also the trade matrix in Online Appendix C). For example, the increase in investment in Belgium, which



Graph 6. Effects across countries (6-year profile, high productivity).
Note: This graph reports the level of real GDP in 2026 expressed in percentage deviation from a no-policy change baseline and for a 6-year profile (even allocation across 2021 until 2026 for all Member States). Blue bars show simulation results from a simultaneous investment stimulus (NGEU). Spillover (orange) is defined as the difference of the coordinated simultaneous NGEU stimulus in all Member States and the stand-alone simulations of the national plans. Two-letter country codes follow EU conventions (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes).

receives a relatively small allocation of NGEU funds, boosts GDP by 0.37% in Belgium and has small spillover effects, the largest of which is in Luxembourg (where spillovers from Belgium increase GDP by 0.03%). The role of bilateral trade linkages becomes clearer when focusing on the more significant recipients of NGEU funds. Greece receives a relatively large share of NGEU, which boosts Greek GDP by 2.92%, but spillovers are relatively modest (the largest of these is in Cyprus, where spillovers from Greece increase GDP by 0.09%). The spillover effects of Spanish public investment are largest for Portugal (0.15%), given the close trade linkages between the two countries. But overall, the largest spillover effects come from Italy, a large country, receiving a major share of NGEU funds. Note that these spillovers are often larger than what bilateral trade linkages would suggest, as they are amplified by third-country effects (i.e. via linkages with other economies outside the bilateral relationship). For example, Germany benefits not only from the direct spillover from higher Italian demand but also from the increased economic activity of Italy's other trading partners, which themselves require imports from Germany to grow.

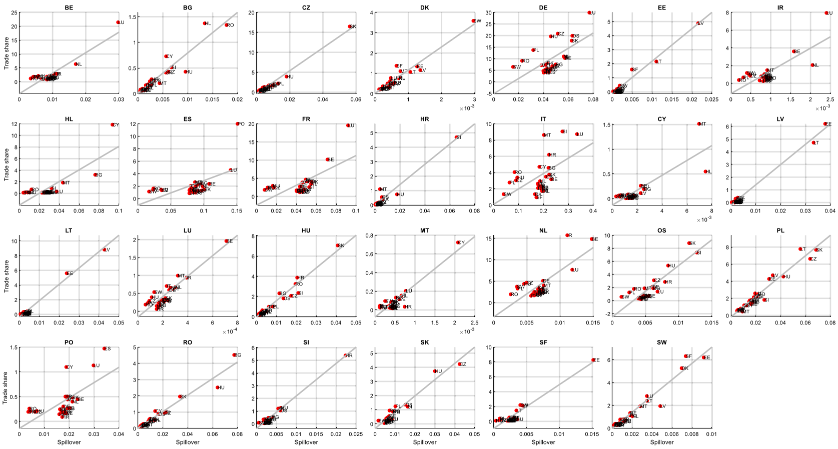
The final row shows the total effects of NGEU for each Member State from the simulation, including all NGEU spending jointly. Looking at the effects per country, one sees that the overall GDP effects for small open economies that receive a small direct allocation of funds can be considerably enlarged by the spillovers from other countries. For example, the direct impact for Belgium is small, but spillovers from other countries to Belgium are more than double this effect.

Graph 7 shows that trade is a central mechanism explaining the effects. For each unilateral investment plan, the graph reports the relation of import shares (as a percentage of GDP) and spillover effects (as in Table 3). Overall, there is a strong relationship between import shares and spillovers, and the output gains are most significant for close trading partners. For example, the Belgian investment increases Luxembourgish GDP the most, while the Czech plan mostly affects the Slovakian economy. Across the different panels and as discussed above, the largest plans (e.g. Italy) have the most pronounced spillover effects on other countries. Besides bilateral trade, the broader production network (third-country effects) and the monetary policy setting also determine spillover effects in the model. The following section will analyze these channels in more detail.

Table 3. Cross-country effects of (counterfactual) unilateral plans and NGEU

	BE	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE
BE	0.37	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00
BG	0.00	2.41	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00
CZ	0.00	0.01	0.86	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.06	0.00	0.00
DK	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.06	0.05	0.05	0.04	0.30	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.08	0.05	0.04	0.06	0.06	0.03	0.05	0.02	0.06	0.06	0.04	0.02
EE	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IE	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EL	0.03	0.08	0.01	0.02	0.02	0.03	0.03	2.92	0.03	0.02	0.03	0.02	0.09	0.03	0.02	0.04	0.01	0.04	0.03	0.03	0.01	0.02	0.01	0.03	0.03	0.02	0.00
ES	0.11	0.09	0.04	0.08	0.08	0.09	0.09	0.08	1.72	0.09	0.08	0.08	0.08	0.09	0.09	0.14	0.04	0.09	0.10	0.09	0.02	0.15	0.02	0.10	0.10	0.08	0.02
FR	0.07	0.05	0.02	0.04	0.04	0.05	0.05	0.04	0.05	0.44	0.04	0.04	0.04	0.05	0.04	0.09	0.02	0.05	0.05	0.05	0.01	0.05	0.01	0.05	0.06	0.04	0.01
HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.07	0.01	0.00	0.00
IT	0.23	0.22	0.09	0.17	0.18	0.19	0.19	0.19	0.19	0.18	0.22	2.28	0.18	0.19	0.18	0.33	0.09	0.20	0.20	0.21	0.06	0.19	0.08	0.28	0.22	0.17	0.04
CY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LV	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.54	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LT	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HU	0.00	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.01	0.01	0.00	0.02	0.02	0.04	0.00	0.00
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NL	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.18	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00
AT	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.25	0.00	0.00	0.00	0.01	0.01	0.00	0.00
PL	0.02	0.02	0.06	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.06	0.02	0.04	0.01	0.02	0.02	1.64	0.00	0.02	0.03	0.07	0.01	0.02
PT	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.00	1.95	0.00	0.02	0.02	0.02	0.00
RO	0.01	0.08	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.06	0.01	0.01	0.02	0.01	0.00	2.75	0.02	0.03	0.00	0.00
SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	1.02	0.01	0.00	0.00
SK	0.01	0.01	0.04	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.00	0.01	0.02	0.01	0.01	0.01	0.02	1.48	0.00	0.00
FI	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00
SE	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.21
NGEU	0.89	3.01	1.20	0.52	0.69	1.36	0.50	3.28	2.09	0.79	2.94	2.54	1.83	2.04	1.61	0.79	1.62	1.09	0.62	0.74	1.83	2.41	2.95	1.66	2.14	0.62	0.34

Note: This table displays cross-country GDP effects after 6 years of the counterfactual unilateral investment plans (by row) on the other countries (by column). For example, the cell in row DE and column BE shows that the unilateral German stimulus plan would increase the level of Belgian GDP by 0.06%, while the cell (BE, BE) shows domestic GDP effects in Belgium of the Belgian investment stimulus alone. Two-letter country codes follow EU conventions (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes). The last row shows the effects of the synchronised NGEU stimulus. Small differences between the column sums and the NGEU effects relate to model non-linearities. All simulations assume a six-year implementation. Table I.1 in Online Appendix I reports corresponding results for a fast implementation scenario.



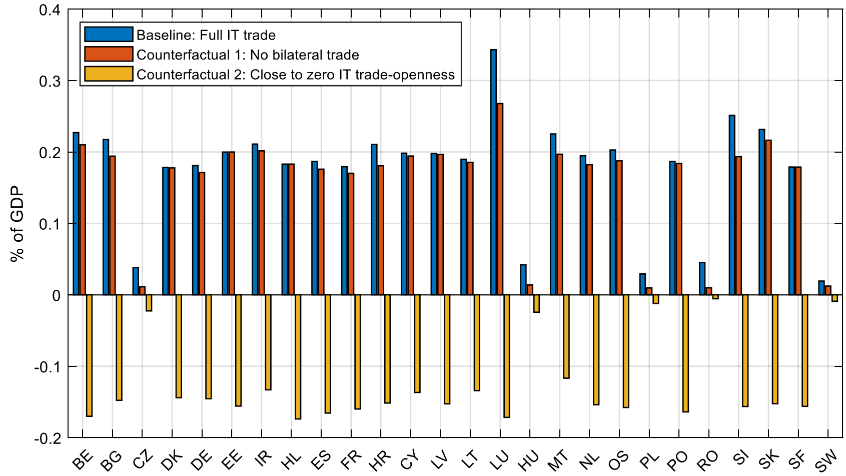
Graph 7. Bilateral trade and spillover effects.
Note: This reports the relation of import shares (vertical axis, in percentage of GDP, see also Online Appendix C, Table C.3) and spillover effects. Each panel shows the GDP effects (in %) after 6 years of the counterfactual unilateral investment plans on the other countries (as reported in Table 3). Solid lines show a linear least-squares fit. Note that the x-scales are different across panels. Two-letter country codes follow EU conventions (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes). All simulations assume a 6-year implementation.

5.6. Spillover channels: the case of Italy

Our main finding is that the spillovers of a coordinated investment stimulus can be sizeable in the EU. We now shed more light on the different transmission channels. Direct trade (export demand) is arguably a major transmission channel for fiscal spillover in the highly integrated European economy, as illustrated in Graph 7. However, there are other potential sources: euro-area members

Table 4. Overview of simulation assumptions: the case of Italy

Scenarios	Bilateral trade with Italy	Italian trade openness (imports as % of GDP)
Baseline scenario	Yes	30%
Counterfactual 1	No	30%
Counterfactual 2	No	<1%



Graph 8. Spillover effects (in % of GDP) of the Italian investment under different scenarios.
Note: This graph displays average GDP effects (in %, 2021–2026) for the baseline and different counterfactual model settings. All results consider the Italian NGEU investment only. All simulations assume a 6-year implementation and high productivity of public investment.

share a common monetary policy and exchange rate. Moreover, countries can benefit from fiscal spillovers via third-country effects even if direct bilateral trade linkages are minor. Given the importance of Italy, the largest recipient country of NGEU funds, the analysis focuses on the (stylized) Italian investment plan.

We contrast the baseline simulation for the Italian investment stimulus presented above with two counterfactuals. First, a "no-bilateral-trade" counterfactual investigates the role of direct trade. We reconsider the Italian public investment but shut down bilateral trade links with Italy one country at a time.[35] This approach gives 26 simulations, one for each EU trade partner of Italy. While the bilateral trade is turned off, other channels remain, such as common monetary policy and third-country effects. A second counterfactual "no-trade" simulation shuts down (almost) all Italian trade linkages and thereby shuts down third-country effects entirely.[36] At the same time, the scenario maintains the common monetary policy, which targets euro-area-wide variables. Table 4 summarizes the different assumptions.

Graph 8 summarizes the results. First, note that sizeable bilateral spillover remains even without direct trade. While perhaps surprising, this finding can be explained by third-country effects, the interest-rate channel, and the exchange-rate channel. Since Italy's NGEU program increases export demand for all trading partners, positive output spillovers are only partially reduced. Moreover, even if the demand for imported goods is absent, euro-area members benefit from a favorable reaction in real interest rates (see the discussion on the effective lower bound above) and an exchange-rate depreciation. The interaction of these channels generates powerful spillover effects: higher spillovers and output effects throughout the EU amplify the transmission via financial markets. As discussed above, with larger GDP effects in each country, this amplification is strongest for a coordinated expansion.

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Our second counterfactual underlines the importance of these interaction effects. When Italy acts as a closed economy in a monetary union, we obtain negative spillovers. Absent trade links, there is no additional demand for foreign goods, but the increase in the real interest rate crowds out demand. Interest-rate differentials then explain the reduced spillovers, in line with Hebous and Zimmermann (2013).[37] As expected, this channel is absent outside the euro area, where the negative effects can be explained by adverse spillover from trading partners in the euro area.

Finally, there are other important factors besides the international linkages exemplified here: the NGEU allocation, the size of the domestic multiplier, the full set of trade linkages (including with third countries), and other country-specific parameters that determine bilateral spillover effects.

6. Conclusion

The EU has responded to the massive economic fallout of COVID-19 with an unprecedented macroeconomic package covering reforms and public investment. Our paper has quantified the macroeconomic spillover effects of the up-to EUR 750bn investment program—a key aspect of the policy debate. We find that the positive macroeconomic spillovers of NGEU are significant. Quantitatively, they could increase the average GDP impact of the stimulus by around one-third. Moreover, spillovers explain most of the domestic GDP gains for some highly integrated economies. A simple aggregation of individual effects of the Member States' plans would thus substantially underestimate the growth effects of NGEU. Bilateral trade linkages are central factors explaining these spillovers, but third-country effects, interest-rate effects, and exchange-rate effects are also important.

For the sake of clarity, our analysis has not taken into consideration some relevant factors. Firstly, reforms are a central element of NGEU alongside investment. Reforms can support medium-run and long-run growth, for example, by increasing labor market participation or improving market conditions that strengthen investment. However, it remains beyond the scope of this paper to model the multitude of concrete reform efforts and market outcomes included in the Member States' plans. Secondly, NGEU generates additional fiscal space. The grant instruments in particular reduce the debt-to-GDP ratio in highly indebted countries. This channel can also reduce risk premia for the banking sector and stimulate private consumption and investment. Thirdly, we have not taken into consideration any details of the country-specific investment and reform plans. We leave these important topics for future research.

Supplementary material. To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1365100522000487

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Notes

1 See European Council (2020) and https://ec.europa.eu/info/strategy/recovery-plan-europe_en.

2 https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en.

3 Our paper also extends earlier Commission estimates [European Commission (2020a, 2020b)].

4 The model in Bergholt and Sveen (2014) is a notable exception.

5 While desirable and relevant for gauging the long-run multiplier by increasing potential output, such an analysis is beyond the scope of this paper, as the required additional assumptions, which would moreover need to differ across Member States, would reduce the clarity and transparency of the analysis.

6 This figure (expressed as a share of 2019 GDP) depends on the assumed loan uptake, which we base on current information. The size of NGEU is likely to increase with additional loan requests.
7 Coelho (2019) uses EU structural fund data to estimate regional output responses to federal expenditure in the euro area. She reports large contemporaneous multipliers of 1.8, growing to an output multiplier of 4.1 after 3 years with a sizeable share due to fiscal spillover effects. The short-run point estimates of the fiscal multiplier are also in line with Chodorow-Reich (2019).
8 On the role of different spillover channels, see also Cardani et al. (2022).
9 The allocation differs for each of the 12 instruments that make up the package. The Recovery and Resilience Facility (RRF) is the largest instrument. Seventy percent of the RRF allocation is based on: (a) the 2019 population, (b) the inverse of 2019 GDP per capita, (c) the 2015–2019 average unemployment rate, and (d) the loss in real GDP observed over 2020 and by the cumulative loss in real GDP observed over the period 2020–2021. The financial allocation considered here is indicative based on the Commission's autumn 2020 economic forecast for real GDP growth in 2020 and 2021. A 30% share will be revised by June 2022, based on actual outturn data from Eurostat (https://ec.europa.eu/info/files/recovery-and-resilience-facility-grants-allocation-member-state_en). However, the total volume includes other instruments such as ReactEU (EUR 48.2bn, in 2019 prices) and the Just Transition Fund (JTF, EUR 10.1bn). For these two funds, we apply the specific allocation key based on current information. For the remaining instruments (Horizon Europe, InvestEU, Rural Development, RescEU), we apply the 70% RRF allocation key. We also assume that ex ante disbursement from the EU budget coincides with received funds (i.e. we do not take into consideration exchange-rate calculations at this stage). Spain has expressed an intention to apply for loans at a later stage in 2022, but this has not been included here. Information on the allocation keys of ReactEU and JTF is available at https://ec.europa.eu/info/files/react-eu-allocations-2021_en and https://ec.europa.eu/info/files/just-transition-fund-allocations-member-state_en.
10 Namely, CY (0.24), EL (12.7), IT (122), PL (12.1), PT (2.7), RO (14.97), and SI (0.705).
11 Online Appendix I.4 presents the main results under distortionary labor taxation. The main effects are in line with the lump-sum case. However, as expected, distortionary labor taxes reduce the positive employment impact. Consumption and output effects also increase less, notably after 2027, when, according to our assumptions, the national governments start to raise the NGEU contributions.
12 Graph G.3 in the Appendix shows the detailed assumptions for all Member States.
13 This assumption means that parts of the RRF allocation used to cover the costs of reforms are modeled as public investment.
14 Support from the RRF cannot substitute for recurring national budgetary expenditure (unless in duly justified cases) (Article 5(1) of the RRF regulation). Still, it has been argued that loans from the RRF could, to some extent, replace general government spending [Corti et al. (2021)], a share of which is current spending. Our hypothetical assumption of lower loan additionality therefore implies a conservative stance.
15 QUEST is the macroeconomic model developed by the European Commission. Compared to Burgert et al. (2020), we simplify the model along some dimensions (we exclude housing, multiple non-EU economies, credit constraints, and labor in the public sector), while we extend its structure to 28 regions, including all EU Member States and include detailed dynamics of public investment.
16 To ease the mathematical notation, we drop any country-specific indices.
17 Detailed milestones and targets specified in the national RRPs can help reduce such delays.
18 See Bonam et al. (2022) on the interaction of time-to-build constraints and the effective lower bound.
19 The simulations below consider $N=4$ (1 year in the quarterly model) and $\psi = \frac{1}{N+1} \forall n$. While some projects will require longer time-to-build lags, other investments can be considered as maintenance, enhancing productivity earlier on. Nonetheless, the productivity effects remain persistent as public capital depreciates only slowly. $N=0$ nests the standard model.
20 With forward-looking households and firms, authorized investment can also generate announcement ("news") effects.
21 The model includes consumption, labor, corporate and lump-sum tax revenue, and employer social security contributions. On the expenditure side, we account for government consumption and investment, transfers, and unemployment benefits.
22 Note that our notation introduces grants and loans as financial flows. The corresponding investment, financed by the grants, is accounted for separately as a cost by changes in the government expenditure term. Thus, grant-financed additional investment is ex ante deficit-neutral.
23 While more accommodative, we allow for a small response to account for (unmodeled) unconventional monetary policy.
24 On the one hand, ignoring the distinction between trade in final goods and intermediates would overstate the importance of "import leakage." On the other hand, productivity improvements also reduce prices for intermediate input, and this cost channel implies additional positive spillover effects (Goldberg and Campa, 2010; Bergholt and Sveen, 2014).
25 Private investment is assumed to consist only of T goods. See Online Appendix B.
26 See, for example, in 't Veld et al. (2015), and Kollmann et al. (2016). Online Appendix I.3 reruns the main simulations under alternative labor-supply parametrisations.
27 Moreover, the productivity effects depend on the level of the initial capital stock (more precisely, the distance to the social optimum), as discussed in Ramey (2020) and Pfeiffer et al. (2021). In our case, long-run multipliers are higher if the

economy starts with a low level of public capital. The model's long-run steady-state condition $K^G = IG/\delta^G$ implies that the depreciation rate (5% p.a.) and the investment share jointly determine the long-run public capital stock. As a result, countries with a larger public investment share in the past two decades (e.g. recipients of Structural and Cohesion Funds) typically have a larger steady-state level of public capital in our model calibrations and hence, all other things being equal, lower multipliers of public investment. Appendix E illustrates these effects quantitatively.

28 The relative strength of the effects on employment and real wages depends, among other things, on the rigidity of real wages.

29 While the model accounts for implementation lags (see above), the simulations do not capture the particular problems related to the lifting of lockdowns. Temporary bottlenecks in global supply chains could lead to additional inflationary pressures, which are not modeled here.

30 The higher the initial debt ratio, the stronger the denominator effect on the ratio in the first year.

31 This result depends on the assumed expenditure rules, as we discuss in more detail in Appendix G.

32 We include the non-additional loans in the calculations, which increase the NGEU volume but do not finance additional public investment.

33 Unlike Ramey (2020), we also account for openness toward the rest of the world, which reduces multipliers as part of the additional demand goes to foreign goods (outside the EU).

34 In this case, the output elasticity of public capital is reduced from 0.12 to 0.05. This stylized recalibration is in line with the lower bound considered in Leeper et al. (2010).

35 The NGEU investment in other Member States is assumed to remain zero in these simulations (unilateral case). The bilateral import share in each simulation is allocated to the rest of the world, keeping the overall Italian trade openness parameter constant across all the simulations.

36 For numerical reasons and to maintain that the NGEU is financed via the EU budget, we set the bilateral trade shares of all countries with Italy to 1/40th of the empirical value instead of zero.

37 We have also run a counterfactual, which, in addition to the no-trade setting, assumes an independent monetary policy for Italy. In this case, as expected, no spillover effects remain, while the stronger domestic interest-rate response reduces the GDP gains in Italy.

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