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# Quantifying Spillovers of Next Generation EU Investment

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and Jan in 't Veld

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# Quantifying Spillovers of Next Generation EU Investment

Philipp Pfeiffer, Janos Varga and Jan in 't Veld

## Abstract

Next Generation EU (NGEU) is an unprecedented tool that provides significant financial support for reforms and investment, resulting in a coordinated fiscal expansion across the EU in response to the COVID-19 pandemic. Thus, fiscal spillovers are relevant for the assessment of its overall macroeconomic effects. We quantify the effects of the additional investment expenditure for each Member State by extending a standard macro model with a rich trade structure. Our model suggests that the EU-wide GDP effects are around one third larger when explicitly accounting for the spillover effects from individual-country measures. A simple aggregation of the national effects of individual investment plans would thus substantially underestimate the growth effects of NGEU. For small open economies with smaller NGEU allocations, spillover effects account for the bulk of the GDP impact. We also quantify the role of key transmission channels, such as the zero lower bound, productivity effects and different assumptions on the disbursement speed. However, the paper does not quantify the impact of structural reforms, which can further enhance the growth impact of NGEU.

**JEL Classification:** E61, E62, F17, F41, F42.

**Keywords:** International spillovers, Public investment, New Keynesian DSGE model, open economy, multi-region, Next Generation EU, European integration.

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## Executive Summary:

The massive economic fallout of COVID-19 has changed the macroeconomic landscape profoundly. In addition to national stabilisation measures, EU-wide policy has responded with an unprecedented macroeconomic package combining reforms and public investment. This package, Next Generation EU (NGEU), is at the heart of the EU response to the coronavirus crisis. Beyond its economic impact, it is a strong sign of European unity and ambition. The significant boost to public investment and reforms also addresses structural issues such as climate change and digitalisation. Financed by issuing a common debt, it is worth up to €750 billion (in 2018 prices; 5.4% of EU GDP in 2019), of which €90 billion will be in the form of grants and the rest in the form of loans for the period 2021–2026.

In macroeconomic terms, NGEU is a unique coordinated investment and reform programme across the EU. Thus, fiscal spillovers via trade flows and financial markets are central for assessing macroeconomic effects. For example, higher public spending in one country can increase import demand for goods and services of its trading partners. This aspect is particularly relevant in the highly integrated EU economy and the monetary union. However, economic analysis and policy commentaries often focus on the impact in a given country based on national NGEU envelopes without considering the beneficial effects of other MS' plans.

This paper contributes to this debate. We use a rich macroeconomic model to quantify the impact and spillover effects of NGEU investments. The framework features all 27 EU Member States and the rest of the world. It combines a dynamic model for fiscal policy analysis with detailed cross border trade linkages, typically only exploited in static input-output analysis and trade models. The model also incorporates core elements of NGEU: grant allocations, favourable loan conditions and new debt issued by the EU with stylised but explicit repayment assumptions.

Overall, the stylised simulations show large macroeconomic effects of NGEU. For a fast spending scenario (four years), with evenly distributed spending between 2021 and 2024, we find that the level of real GDP in the EU-27 can be around 1.5% higher than without NGEU investments (in 2024). A significant part of this impact comes from spillover effects, pointing to the benefits of joint action. Beyond the direct impact of their own national envelope, countries will also benefit considerably from the effects of NGEU investments in other MS, mainly through trade flows and exchange rate movements. Taken together about one-third more than the sum of individual-country measures. A simple aggregation of the national impacts of individual investment plans would thus substantially underestimate the growth effects of NGEU. In small and open economies, the relative impact of cross-country spillovers is the largest. In these highly integrated economies, spillover accounts for the bulk of the growth impact, while less open economies benefit primarily from the impact of their own allocation. Additional simulations quantify the role of key transmission channels, such as the zero lower bound on nominal interest rates, productivity effects of public investment and different assumptions on the disbursement speed. However, the paper does not quantify the impact of a structural reforms, which can further enhance the growth impact of NGEU.



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# 1. INTRODUCTION

The economic fallout of COVID-19 has changed the macroeconomic landscape profoundly. In addition to national stabilisation measures, EU-wide policy has responded with an unprecedented macroeconomic package that provide large financial support to reforms and public investment, while also addressing long-term challenges such as climate change and digitilisation. This package, Next Generation EU (NGEU), is at the heart of the EU response to the coronavirus crisis. Financed by issuing a common debt, it is worth up to €750 billion (in 2018 prices; 5.4% of EU GDP in 2019), of which €390 billion will be in the form of grants and the rest in the form of loans for the period 2021–2026.<sup>1</sup> Beyond its economic impact, it is a strong sign of European unity and ambition.

In macroeconomic terms, NGEU is a unique coordinated investment and reform programme across the EU. Thus, fiscal spillovers are central for the assessment of its macro effects. However, economic analysis and policy commentaries often focus on effects in a given country without considering the beneficial effects of investment plans in other Member States (MS). 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.<sup>2</sup> While warranted for the national RRP, this perspective overlooks potentially large spillovers given the strong trade linkages in the EU and the euro area. The need for a large model capturing spillover effects with detailed trade structures also brings about methodological challenges. This paper fills this gap by quantifying macroeconomic spillover effects in a rich model distinguishing all 27 MS and the rest-of-the-world.

Our paper also contributes to a wider debate on the macroeconomic effects of NGEU. One line of criticism argued 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 stabilisation scheme at the EU level to ensure a fast disbursement. Their study also provides a stylised impact assessment of NGEU, showing significant macroeconomic effects of NGEU. However, by directly assuming the fiscal multipliers based on national NGEU allocations, their study abstracts from fiscal spillovers and other richer transmission mechanisms, which is the focus of our paper. By contrast, Picek (2020) finds large spillover effects, in particular for MS with smaller grant allocations. However, the static input-output approach does not account for macroeconomic dynamics and second-round effects.<sup>3</sup> In general, some of the wider debate focussed on the allocation of funds, not the macroeconomic impacts and ignored cross border spillover effects, which, in deeply integrated European economies, can be substantial.

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 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, e.g. related to contracting time and planning horizons. Together with time-to-build frictions, such delays reduce the short-run multiplier of government investment as emphasised in Leeper et al.

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<sup>1</sup> European Commission (2021).

<sup>2</sup> [https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility\\_en](https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en)

<sup>3</sup> Our paper also extends earlier Commission estimates (European Commission, 2020a,b).

(2010) and Ramey (2020). By contrast, unlike government consumption, public investment can entail a sizeable long-run multiplier by increasing potential output.

We then embed this augmented model into a multi-country structure designed for spillover analysis and featuring rich trade linkages. Each of the 27 countries and the rest-of-the-world, with all elements of the outlined macro-fiscal setup, is linked to all other economies via trade and financial markets. In particular, a detailed empirical trade matrix covering both goods and services trade explicitly accounts for bilateral trade linkages of all regions. Unlike most models, which counterfactually include only trade in final goods, we explicitly model also trade in intermediate inputs. This approach helps accounting for highly integrated cross border value chains, an important consideration for fiscal spillovers. As a result, our analysis combines attractive features of a dynamic microfounded model with detailed cross border linkages, typically only exploited in static input-output analysis and trade models.<sup>4</sup>

We apply this novel framework to quantify macroeconomic spillover of NGEU investments, a key aspect in the ongoing policy debate. While necessarily simplifying the full mechanics of NGEU, we distinguish grant and loan allocations for each MS based on the currently available information (as of June 2021). Yet, we do not model specific RRP. Notably, our results do not include reforms or other programmes beyond a broad notion of public investment. 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 MS, would reduce the clarity and transparency of the analysis. In that respect our results may underestimate the overall impact, in particular for the long run. We consider two stylised time profiles for the investment programme, a six-year profile spreading the NGEU allocations over six years and a faster profile spanning just four years. In our model, the increase in EU debt associated with NGEU is fully taken into account. A separate EU budget accounts for the new EU-wide debt that is financed via long-term contributions of the MS.

Our simulations show large macroeconomic spillovers of NGEU. Comparing results for a counterfactual unilateral versus the actual synchronised NGEU allocation quantifies this spillover effects for all MS. Our results suggest that the EU-wide GDP effects are around one third larger when explicitly accounting for spillover effects of foreign-induced demand and exchange rate effects. A simple aggregation of individual effects of the MS's plans would thus substantially underestimate the growth effects of NGEU.

Decomposing GDP effects into direct effects and spillovers reveals strikingly different patterns across MS. For small open economies with smaller grant allocations, spillover effects account for the bulk of the GDP impact. In some cases, such as Luxemburg and Ireland, positive spillovers explain almost all of the total impact. However, also for larger economies with deep trade integration, such as Germany, spillovers accounts for more than half of the GDP effect. By contrast, given their larger NGEU allocations and rather closed economies, domestic effects typically dominate in countries such as Bulgaria, Croatia, Greece and Italy. Specifically for MS that are both outside the euro area and the European Exchange Rate Mechanism (ERM-II), the monetary policy reaction and exchange rate response matters for the short-run spillovers. With fully flexible exchange rates, there can be a negative short-run spillover for those countries due to national currency appreciation (while the total GDP effects remain positive). However, this temporary effect vanishes in the second year, and it depends on the exchange rate policy.

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<sup>4</sup> The model in Bergholt and Sveen (2014) is a notable exception.

Overall, the stylised simulations show large macroeconomic effects of NGEU. Given currently available information on loan uptake, NGEU investment is about 4% of EU GDP.<sup>5</sup> For a fast spending scenario (four years), with evenly distributed spending between 2021 and 2024, we find that the level of real GDP in the EU-27 can be around 1.5% higher in 2024 than foreseen in a no-policy change baseline. When it is assumed that the NGEU plan lasts six years (2021 to 2026), the GDP gains reach 1.2% in 2026. 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 will depend on several factors, including the productivity-enhancing effects of the investment stimulus, the monetary policy reaction, and the speed of disbursement. Additional model simulations shed light on the multiplier and the macroeconomic effects of public investment for alternative assumptions on these parameters, but do not cover other macroeconomic channels, in particular the contribution of reforms to lift potential growth or the mutually reinforcing effects of combining reforms and investment. For example, when monetary policy keeps nominal rates roughly constant, spillovers are larger. In this case, the accommodative monetary policy reduces crowding-out effects. By contrast, if monetary policy is active in line with a standard Taylor rule, nominal rates increase by more than inflation. The corresponding increase in real interest rates crowds out domestic demand. Assuming a low productivity of the investment also reduces the multiplier effects significantly, in particular in the long run, when the supply-side improvements matter most.

**Related literature.** The current expansionary fiscal stance is in many ways a reversal of the austerity debate of the last decade, and our analysis contributes to a growing literature on fiscal spillovers in the EU. A large body of literature has tried to quantify spillovers using macroeconomic models, identifying a direct demand channel and a competitiveness channel related to inflation differentials and exchange rate movements. In 't Veld (2013) showed model simulations with the Commission's QUEST model in which negative spillovers of fiscal consolidations in Germany and other core EA countries in 2011-13 added between 1½ and 2½ pps. to the negative growth effects in Greece and other Member States in the periphery. Attinasi et al. (2017) partly contradicted this, arguing that the spillovers were smaller in the New Multi-Country Model of the ECB due to a cross-border confidence channel and risk premium effects.

Using a multi-region version of GIMF, Elekdag and Muir (2014) looked at the effects of a two-year boost to government investment in Germany of 1% of GDP. 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. At the zero lower bound with constant policy rates, higher inflation rates lead to lower real interest rates, boosting domestic demand in Germany and the rest of the euro area, and leading to a depreciation, further increasing net exports. Under an accommodative monetary policy, when the ECB does not react with a monetary tightening, increased public investment has sizeable positive spillovers to the rest of the euro area of between 0.2 and 0.3%. Blanchard et al. (2015) analyse the spillover effects of a fiscal expansion in core euro area countries on the peripheral countries using a New Keynesian model for a currency union. Their study finds the size of the effects on the periphery GDP to be large in a liquidity trap. In 't Veld (2016) showed model-based simulations of an increase in public investment in Germany and the Netherlands and their spillovers to the rest of the euro area. While spillovers in a monetary union may be small when monetary policy reacts by raising interest

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<sup>5</sup> 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.

rates, when rates are kept constant, and the stimulus is accommodated, spillovers on the rest of euro area GDP can be sizeable. NiGEM model simulations in Deutsche Bundesbank (2016) also show the crucial role of the monetary policy reaction. With constant interest rates, a two year increase in public investment of 1% of GDP raises GDP in Germany by 0.5%, while euro area spillovers are between 0.1-0.3%. The authors emphasise the importance of the assumed import share. For government consumption, which is largely 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. Government investment is likely to have a large import content and hence larger spillovers. Corsetti et al. (2010) discuss key determinants of spillover effects, namely trade openness, trade elasticities and budgetary assumptions. Cacciatore and Traum (2020) discuss the role of the trade channel in more details and also report positive spillover effects using an estimated model for the US and Canada.

There is also an extensive empirical literature analysing fiscal spillovers adopting different empirical methodologies and alternative approaches to identify fiscal shocks. Beetsma and Giuliodori (2004) and Beetsma et al. (2006) use VAR analyses to estimate fiscal spillovers in the EU and find that a 1 percent increase in German government spending can lead to an output response that varies between 0.05 percent of GDP in Greece and 0.4 percent of GDP in Belgium. Auerbach and Gorodnichenko (2013) use panel data of OECD countries to estimate fiscal spillover multipliers. They find that fiscal stimulus in one country is likely to have economically and statistically significant effects on output in other countries and 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. Their estimates imply a greater impact than would be implied simply by the ratio of imports to government spending. Hebous and Zimmermann (2013) estimate a global autoregressive model (GVAR) and find spillovers of mixed sign, but their identification relies on orthogonalised response functions, which cannot be interpreted in a structural sense. Dabla-Norris, Dallari, and Poghosyan (2017) estimate a panel VAR model that captures cross-country, dynamic interlinkages for 10 euro area countries using quarterly data from 1999-2016. Their analysis suggests that 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. 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 a multiplier of 4.1 after three years. A sizable share of the output and employment effects is due to fiscal spillover effects. The short-run point estimates of the fiscal multiplier are also in line with Chodorow-Reich (2019). Ilori et al. (2020) estimate a BVAR model and find significant positive spillovers of government spending shocks between Germany and other EU economies as well as between the US and the G7 countries. Using structural VAR models, Klein and Linnemann (2021), too, report sizable positive spillover effects of 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 the estimates of Corsetti and Müller (2013).

The remainder of this paper is as follows. Section 2 discusses our assumptions on NGEU. Section 3 describes the key modelling relationship, while relegating the mathematical details to the Appendix. Section 4 presents our main results. Section 5 concludes.

## 2. NEXT GENERATION EU

### 2.1. A HISTORIC INVESTMENT AND REFORM PACKAGE

The recovery instrument Next Generation EU (NGEU) aims to repair the immediate economic and social damage brought about by the coronavirus pandemic, and make Europe greener, more digital, more resilient and better fit for the current and forthcoming challenges. It is a temporary instrument to boost the EU's long-term budget (the multiannual financial framework, 2021-2027). Designed in response to the COVID-19 pandemic, one of the main elements of NGEU is the Recovery and Resilience facility, which aims at providing large scale financial support to sustainable reforms and related public investments with the explicit long-run goal to support green investment, digitalisation and resilience more broadly.

### 2.2. A STYLISED COMPOSITION AND ALLOCATION

Modelling NGEU requires several simplifying assumptions. First, we broadly partition the total package into grant and loan instruments, summarised in Table 1, totalling around 4% of EU GDP.

The allocation differs for each of the twelve different instruments that make up the package, but for the RRF, the largest of the funds, is based on: (a) 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 allocation is thus largely based on pre-COVID economic data, while taking the impact of COVID into account. It was designed to favour lower-income and vulnerable countries as well as those particularly hard-hit by the pandemic.

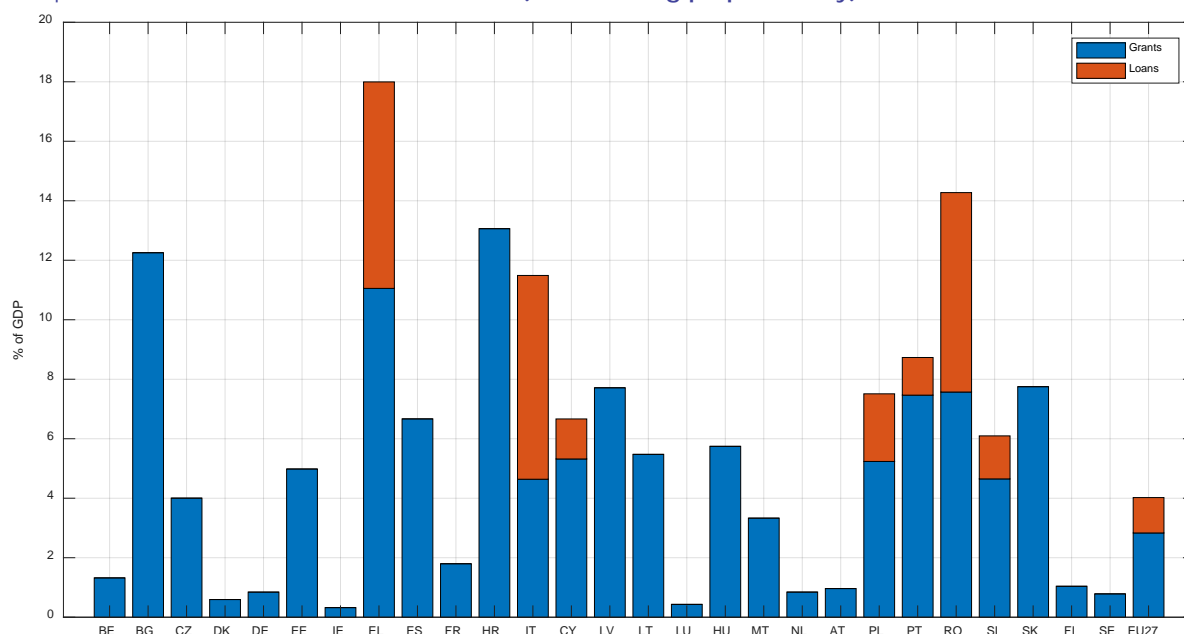
Table 2.1. Apportioning across NGEU instruments (for modelling purposes only)

	EUR bn
Grant instruments	396
<i>of which RRF grants</i>	<i>317</i>
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 stylised representation for modelling purposes only; actual sums financed from NGEU are bound to differ. Grant instruments include RRF grants and additional resources such as Re-actEU 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.

Graph 2.1. Overview of assumed allocation (for modelling purposes only)



Note: This figure reports the assumed grant and loan allocation used in the simulations. Note that this is a highly stylised representation for modelling 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](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

The Recovery and Resilience Facility (RRF) is the largest instrument of NGEU. A large share of the NGEU package boosts public investment in the forms of grants.<sup>6</sup> The allocation across MS is based on the current RRF maximum grant allocation. In total, the simulations assume that EUR 396bn (or EUR 421bn in current prices) will be provided in the form of grant instruments. This total volume includes other instruments such as ReactEU (48.2bn) and the Just Transition Fund (JTF, 10.1bn).<sup>7</sup> For these two funds, we apply the specific allocation key based on current information.<sup>8</sup> For the remaining instruments (Horizon Europe, InvestEU, Rural Development, RescEU), we apply the 70%-RRF allocation key.<sup>9</sup>

Regarding loans, we assume that seven MS request a total of 166bn EUR in RRF loans, based on current information (08/06/21), namely, CY (0.24), EL (12.7), IT (12.2), PL (12.1), PT (2.7), RO (14.97) and SI (0.705). Note, however, that the loan amount is expected to increase as several MS have indicated that they would intend to ask for loans at a later stage.

<sup>6</sup> The current maximum financial allocation 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](https://ec.europa.eu/info/files/recovery-and-resilience-facility-grants-allocation-member-state_en)

<sup>7</sup> In 2019 prices.

<sup>8</sup> Information on the allocation keys of ReactEU and JTF is available at [https://ec.europa.eu/info/files/react-eu-allocations-2021\\_en](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](https://ec.europa.eu/info/files/just-transition-fund-allocations-member-state_en)

<sup>9</sup> We assume that ex-ante disbursement from the EU budget coincides with received funds (i.e. we abstract from 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.

### 2.3. FINANCING ASSUMPTIONS

We distinguish assumptions on grant and 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 MS contribute to the EU budget according to their current GDP shares, abstracting from future changes in the GNI-shares or new own EU resources. Domestic lump-sum tax finance these contributions.

The RRF loan repayment by the MS that receive loans begins in 2031 and end in 2050 (following a linear schedule). Interest rates for highly indebted countries are at a more favourable, lower interest rate. Loan repayments by the MS are also financed via domestic lump-sum taxation. Graph 12.2 in Appendix shows the detailed assumptions for all MS.

### 2.4. FURTHER SIMPLIFYING ASSUMPTIONS

We make three additional simplifying assumptions. First, the simulations assume an even allocation across the years of NGEU's active operation. We consider a six-year profile (i.e. 16.67% each year from 2021 to 2026) and a fast scenario, featuring an even allocation across four years (2021-2024). The assumed profile is the same for all NGEU components and for all MS.

Second, the simulations assume 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 modelling purposes, we consider it as productive spending (see next section).<sup>10</sup>

Finally, the simulations assume that MS 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 resources), the impact on the national debt is also 50%.<sup>11</sup>

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<sup>10</sup> This means that also parts of the RRF allocation that is used to cover the costs of reforms are modelled as public investment here.

<sup>11</sup> Support from the Facility cannot substitute recurring national budgetary expenditure (unless in duly justified cases) (Article 5(1) of the RRF regulation), but many observers have argued that loans from the RRF would to some extent replace other borrowing that finances general government spending, a share of which is current spending. Our hypothetical assumption of lower additionality of loans implies our macro-economic assessment errs, if anything, on the conservative side.

## 3. A MODEL FOR FISCAL SPILLOVER ANALYSIS

This section provides a birds-eye view of key modelling relationships. To quantify fiscal spillover effects, we consider a rich multi-region dynamic general equilibrium model, distinguishing all 27 EU Member States and a rest-of-the world (RoW). Our starting point for each region is a macroeconomic workhorse model, the European Commission’s QUEST model.<sup>12</sup> The framework incorporates the main features relevant for fiscal policy transmission, as identified 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 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. the participation in the euro area or the European Exchange Rate Mechanism (ERMII), or independent national currencies.

Our main innovation is to embed this workhorse model into a multi-country structure with rich trade features designed for spillover analysis. A detailed trade matrix explicitly accounts for bilateral trade linkages of all 28 regions. The model captures linkages through cross-border value chains by including trade in intermediate inputs for tradable and non-tradable sectors. The calibration of the model is based on national accounts data, input-output tables and international trade matrices for the long-term properties and sectoral and international linkages, and on estimated model versions for the parameters governing transitional dynamics.

We now briefly sketch the model’s government, firm and household sectors of the regional blocks. These elements are isomorphic in each region. We then discuss the detailed trade linkages between the different regions. Combining both aspects into a larger model is our main modelling contribution, allowing us to quantify the fiscal spillover of NGEU. We keep exposition mostly non-technical, relegating the mathematical description to Appendix B.<sup>13</sup>

### 3.1. FISCAL POLICY

#### 3.1.1 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, labour). Following Baxter and King (1993), we can write a simplified representation of the private-sector production function as:

$$Y_t = N_t^\alpha K_t^{1-\alpha} (K_t^G)^{\alpha_G}, \tag{3.1}$$

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<sup>12</sup> 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 labour in the public sector), while we extend its structure to 28 regions, including all EU Member States and include detailed dynamics of public investment.

<sup>13</sup> To ease the mathematical notation, we also drop any country-specific indices.



where  $Y_t, K_t, N_t, \alpha$  and  $K_t^G$  denote output, private capital, labour, the labour share, and effective public capital, respectively. The output elasticity of public capital,  $\alpha_G \geq 0$ , drives the medium and long-run GDP effects in our simulations. To calibrate this crucial parameter, we follow the empirical literature. These studies, however, have found different degrees of productivity. Our main calibration takes the (meta-)estimate of Bom and Ligthart (2014). For robustness, we also consider a lower productivity scenario.

Besides its supply-side effects, public investment enters GDP in the national account expenditure items directly. Therefore, *ceteris paribus* (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.

### 3.1.2 Public investment: Time-to-build and time-to-spend

Public investment often faces implementation and construction delays. For example, projects need to be contracted.<sup>14</sup> 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).

These features have two main implications. First, government investment is not immediately productive, reflecting time-to-build lags. Thus, in contrast to the standard model, government investment does not translate immediately into productivity-enhancing public capital. Instead, with the time-to-build delay, the positive supply-side effects materialise 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:

$$K_t^G = (1 - \delta^g)K_{t-1}^G + A_{t-N}^{IG}, \quad 3.2$$

where  $A_{t-N}^{IG}$  denotes authorised investment and  $\delta^g$  the depreciation rate of public capital.<sup>15</sup> We model NGEU as shocks to authorised investment.

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

$$I_t^G = \sum_{n=0}^N \psi_n A_{t-n}^{IG}, \quad 3.3$$

where the parameters  $\psi_n$ , with  $n \in \{0, \dots, N\}$ , govern the speed of implementation. With this feature, authorised investment only gradually leads to higher (public) investment demand. Thus, unlike in the standard model, the positive direct demand-side effects do not unfold immediately, too.<sup>16</sup>

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<sup>14</sup> Detailed milestones and targets agreed in the national RRP can help reduce such delays.

<sup>15</sup> The simulations below consider  $N = 4$  (one year in the quarterly model). While some projects will require longer time-to-build lags, other investment can be considered as maintenance, enhancing productivity earlier. Nonetheless, the productivity effects remain persistent as public capital depreciates only slowly.  $N = 0$  nests the standard model.

### 3.1.3 Government budget

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

$$B_t^G = (1 + r_{t-1}^g)B_{t-1}^G - Exp_t + R_t^G - GR_t^{EU} + CO_t^{EU} + \omega^{EU} r_{t-1}^g B_{t-1}^{G,EU}, \quad 3.4$$

where  $Exp_t$  and  $R_t^G$  summarise the government's expenditure and revenues, respectively.<sup>17</sup> 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 stabilise the debt-to-GDP ratio. Receiving a grant ( $GR_t^{EU}$ ) decreases government debt. By contrast, loans increase debt. These back-to-back loans will be repaid gradually by the beneficiary MS. In the long run, we assume that lump-sum contributions ( $CO_t^{EU}$ ) finance the EU budget.  $B_t^G$  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 favourable RRF loan rate, a fiscal expansion would imply an increase in the government bond rate. The term  $r_{t-1}^g B_{t-1}^{G,EU}$  captures contributions to interest rate payments of EU debt, weighted by the country's GDP share in the EU, denoted  $\omega^{EU}$ . The EU budget aggregates the EU debt issued to finance grants and loans.

## 3.2. MONETARY POLICY AND ZERO LOWER BOUND

As we show below, 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 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 European Exchange Rate Mechanism (ERMII). The remaining MS implement their independent national monetary policy with a floating exchange rate. To proxy the current low-interest environment, we assume that monetary policy is accommodative for six quarters in response to the investment stimulus.<sup>18</sup> Below, we also simulate the model without this assumption to gauge the role of monetary accommodation.

## 3.3. HOUSEHOLD HETEROGENEITY AND STICKY WAGES

A rapidly growing literature has emphasised the role of household heterogeneity as important for the transmission of macroeconomic policy, including the relative contribution of direct and indirect effects (e.g., Kaplan et al., 2018). Given the richness of the multi-country 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 Ricardian (optimising) 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 labour and goods markets, this feature implies a higher sensitivity of consumption to income, generating Keynesian effects of fiscal stimulus, in line with empirical evidence (see e.g. Galí et al., 2011).

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<sup>16</sup> With forward-looking households and firms, authorised investment can also generate announcement ("news") effects.

<sup>17</sup> The model includes consumption, labour, corporate and lump-sum tax revenue, and employer social security contributions. On the expenditure side,

<sup>18</sup> While more accommodative, we allow for a small response to account for (unmodelled) unconventional monetary policy.

### 3.4. INTERNATIONAL LINKAGES

At the heart of our spillover analysis is a rich trade structure linking the individual economies. We distinguish between tradable and non-tradable goods and services and explicitly model intermediate inputs. The latter capture cross border value chains and have important implications for spillovers. On the one hand, ignoring the distinction between trade in final goods and intermediates would inflate the importance of bilateral trade spillovers as all additional export demand would be counted as GDP. On the other hand, productivity improvements also reduce prices for intermediate input. This cost channel implies additional positive spillover effects (Goldberg and Campa, 2010; Bergholt and Sveen 2014).<sup>19</sup>

### 3.5. REAL FRICTIONS

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

### 3.6. CALIBRATION STRATEGY

#### 3.6.1 Main model parameters

Model parameters that characterise the model's steady state are calibrated based on national accounts, fiscal and trade data. Behavioural parameters that govern the dynamic adjustment to shocks are based on earlier estimated QUEST model versions.<sup>20</sup> Macroeconomic aggregates that characterise the steady state, like private and public consumption and investment, trade openness, and trade linkages are calibrated on region-specific data. Price and wage adjustment cost parameters, which determine the sensitivity of prices and wages to demand and supply shocks, are informed by evidence of average frequencies of price and wage adjustment.

The steady-state import share in demand for tradables and the share of intermediates in tradable and non-tradable sector production are 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 for goods trade and EUROSTAT, OECD and WTO data sources for services. Finally, the baseline government debt-to-GDP ratio reflects average debt-to-GDP ratios observed over the last 5 to 10 years. Appendix C reports further details on the calibration strategy and data sources.

#### 3.6.2 Productivity effects of public investment

A key aspect of our paper are the productivity effects of public investment. In calibrating the long-run output elasticity of public capital,  $\alpha^G$ , we follow the empirical literature. These studies, however, have found different degrees of productivity. A meta-study (Bom and Ligthart, 2014) finds a mean output elasticity of public capital of 0.12. For robustness, we also consider the case of  $\alpha^G = 0.05$  as a low productivity scenario.

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<sup>19</sup> Furthermore, we distinguish a tradable (T) and a non-tradable (NT) sector to capture realistic real exchange rate dynamics in response to the public investment shock.

<sup>20</sup> See for example in 't Veld et al. (2015), and Kollmann et al. (2016).

Moreover, the productivity effects depend on the level of the initial capital stock, as discussed in Ramey (2020).<sup>21</sup> In our case, long-run multipliers are higher if the economy starts with a low level of public capital. Note that in the model’s long-run steady state the condition  $K^G = I^G / \delta^g$  links public capital and investment.<sup>22</sup> Thus, the depreciation rate (5% p.a.) and the investment share jointly determine the long-run public capital stock. We calibrate the latter using AMECO’s average public investment rates (2000-2020). As a result, countries which had 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 else equal, lower multipliers of public investment. We see this calibration strategy as an attractive way to capture absorption issues of NGEU funds. Appendix E illustrates these effects quantitatively.

### 3.6.3 Nonlinear model solution

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

## 4. NGEU MACRO IMPACT AND SPILLOVER EFFECTS

### 4.1. SIMULATION SETUP

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

### 4.2. EU-WIDE RESULTS: LARGE SPILLOVERS

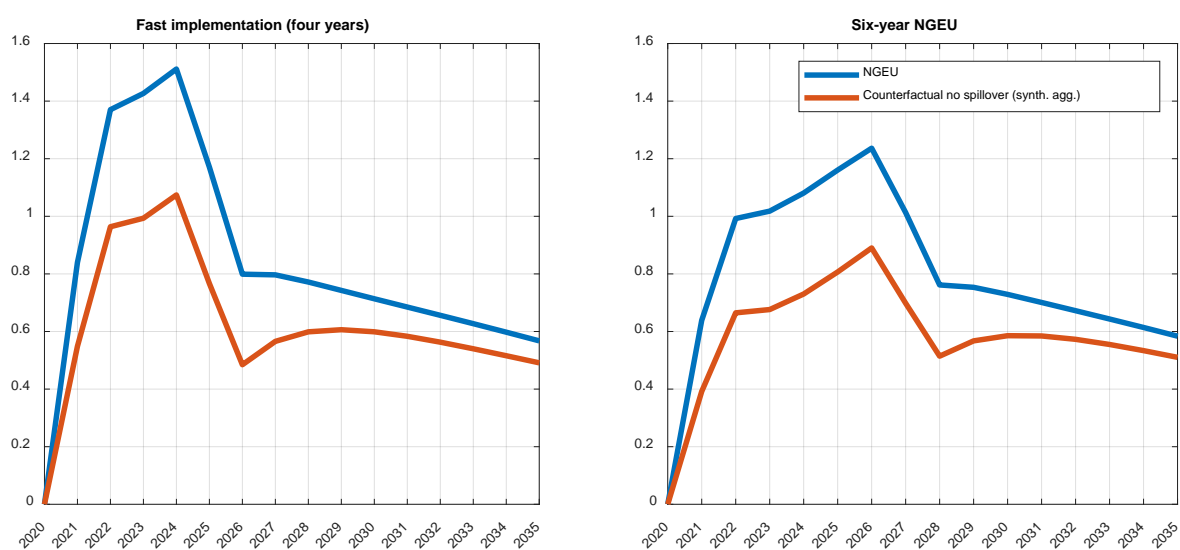
Macroeconomic spillovers of NGEU are significant. Graph 4.1 (right panel) shows that the EU-wide GDP effects are around one third larger when explicitly accounting for spillover effects. The simulations also suggest substantial growth effects of NGEU. Real GDP in the EU-27 is estimated to be more than 1.2% higher in 2026 compared to a no-policy change baseline (blue lines). 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 materialise 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. When appropriations cover four instead of six years, EU-wide GDP rises 1½% above the no-NGEU baseline (left panel in Graph 4.1).

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<sup>21</sup> More precisely, the multiplier depends on the distance to the social optimum. See Pfeiffer et al. (forthcoming) and the Appendix in Ramey (2020) for a formulation of a social planning problem.

<sup>22</sup> This relation is obtained by combining eq. 3.2 and 3.3.

Graph 4.1. Main simulation results: The role spillover for EU-27 growth



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

By contrast, ignoring positive spillovers reduces the macro impact significantly. By aggregating the 27 stand-alone simulations of the unilateral plans, we can construct a synthetic EU GDP (orange lines in Graph 4.1). Excluding spillover effects in this way, we find GDP effects of around 0.8 and 1.1%, depending on the time profile. Thus, simply aggregating individual effects of the MS's plans would substantially underestimate the overall growth effects of NGEU.

The level of real GDP remains persistently high even after the disbursement period(s): 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, sizable medium-run real wage gains accompany the rise in real GDP.

### 4.3. INSPECTING THE MECHANISM

**Domestic effects.** We can distinguish between domestic demand 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 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 authorised investment gradually increases implemented investment (time-to-spend delays). Thus, *ceteris paribus* (absent crowding-out effects), higher investment demand drives up output independently of assumptions on productivity. In sum, public investment in the model increases aggregate demand in the short run and aggregate supply in the medium and long run.

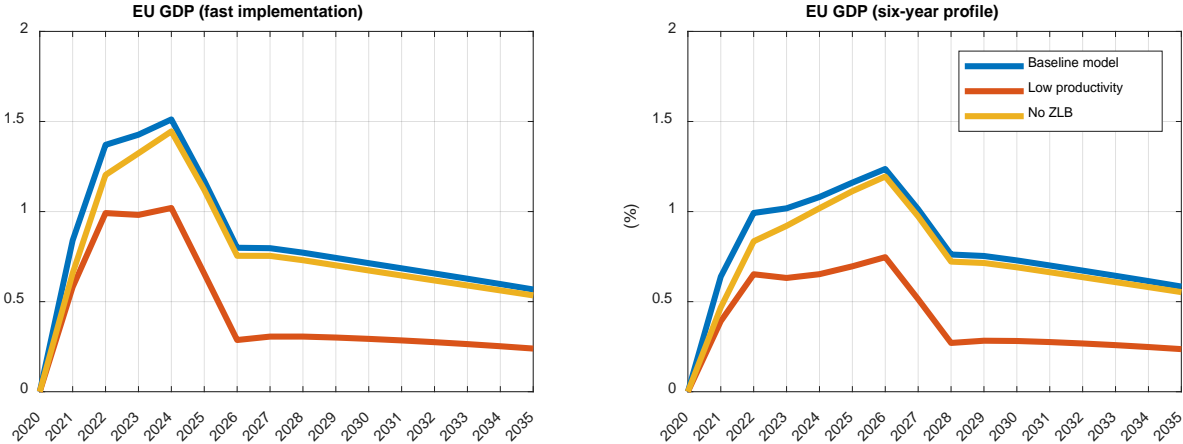
**Spillover.** Two main channels contribute to the large spillovers: direct trade effect and exchange rate effects. First, the increase in domestic activity and import demand is the most direct source of positive GDP spillovers. With trade in intermediate inputs, the positive spillover to the import demand and foreign GDP relates to import of final goods and imports of intermediate inputs into domestic production. This spillover effect will benefit particularly export-intensive countries because of rising demand

from trading partners. 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, i.e. European exports prices increase less than the prices of foreign goods and services. Consequently, EU exports increase.

Second, there is an additional exchange rate effect. At the ZLB, with accommodative monetary policy, relatively lower real interest rates imply (ceteris paribus) a depreciation of the euro, i.e. domestic goods prices increase less than the prices of foreign goods. The exchange rate movement then supports exports. Absent exchange rate policies, this positive short-run spillover effect is absent or even reversed for non-euro area MS, which do not participate in the ERM-II.

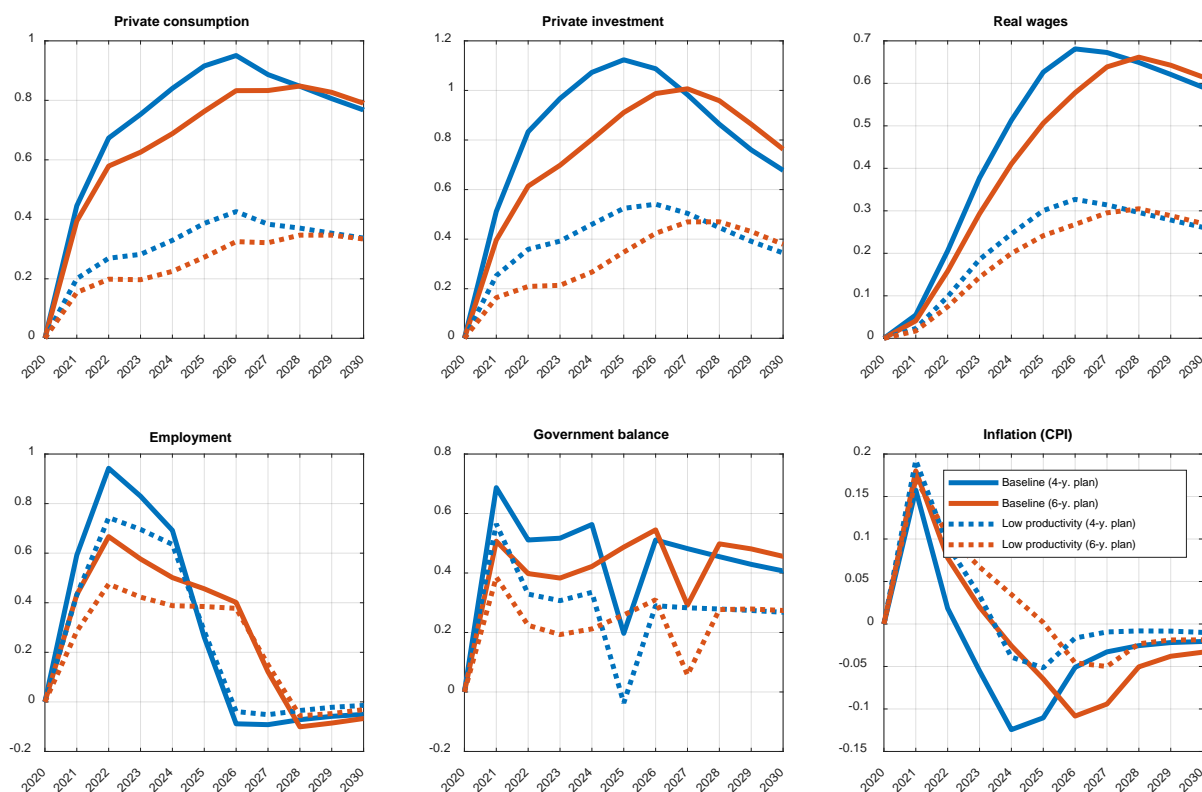
**Effective lower bound and accomodative monetary policy.** Graphs 4.3 and 4.4 further illustrates the effect of monetary policy operating at the effective lower bound. At the current juncture, with the policy rate at the lower bound and inflation below target, we assume that the central banks will accommodate the expansion and not raise interest rates. Therefore, without an increase in the policy and real interest rate (and given positive employment effects) private consumption and investment expand. As a result, the first- and second-year GDP effects of the government investment stimulus increase. On impact, private consumption and investment increase more strongly absent an increase in the policy and real interest rate. Under both monetary policy assumptions, however, 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.

Graph 4.3. Inspecting the mechanism



Note: This graph reports the level of real GDP in percent deviation from a no-policy change baseline. The left (right) panel displays simulations based on six-year (four-year) profile. Blue lines show simulation results from the baseline model (NGEU). Yellow lines display simulations without effective lower bound (ZLB) constraint. Orange lines display a low productivity scenario, setting the output elasticity of public capital ( $\alpha^G$ ) to 0.05.

Graph 4.4. Macroeconomic transmission



Note: This graph reports the government balance (in % of GDP) and inflation (all other variables) in percentage point (percent) deviation from a no-policy change baseline. All results refer to simulation results from the baseline model (NGEU) assuming a six-year implementation. Blue (orange) lines show simulation results from a four-year (six-year) profile. Dotted lines display the corresponding low productivity scenarios.

**Labour markets.** The model simulations suggest a sizable short-run increase in employment and persistent real wage gains (Graph 4.4). The positive employment effect stems from stronger domestic demand. As productivity increases, the (percentage) employment impact is smaller than the GDP impact. Also, for a public investment shock only (without accompanying labour market reforms), the effects are relatively short-lived. By contrast, real wages reflect the improved labour 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 reverts.<sup>23</sup> Note, however, that the simulations presented in this paper only consider a public investment shock and not reform measures that are included in national RRP and have the potential to strengthen productivity growth. By contrast, reforms targeting labour markets can lead to large positive employment effects in the medium and long run (Varga and in 't Veld, 2014).

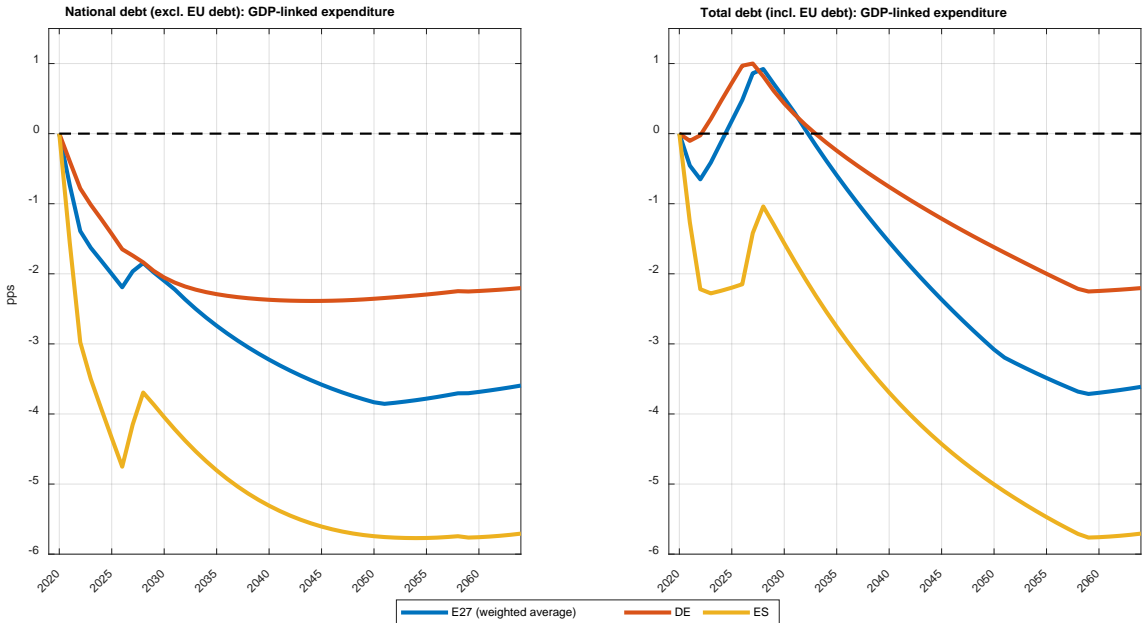
**Fiscal position and inflation.** The spending boost raises inflation, but this is short-lived. While the initial demand stimulus implies (all else equal) a positive output gap, this gap gradually closes again

<sup>23</sup> The relative strength of the employment and real wages depends, among others, on the rigidity of real wages.

as, following the public investment stimulus, potential output catches up with demand.<sup>24</sup> Governments' fiscal positions improve as the growth stimulus raises tax receipts and reduces the need for financial support to the unemployed. This leads to a reduction in national debt ratios, as illustrated in Graph 4.5 (left panel) over a longer horizon.<sup>25</sup>

The model accounts for EU-wide debt associated with NGEU, but does not incorporate the inter-institutional agreement that this debt will be repaid by new own resources. Hence, for net contributors, like e.g. Germany, there is an increase in the overall debt ratio that includes the country's share in EU-wide debt. But after the initial accumulation, debt gradually falls due to higher growth (Graph 4.5 right hand panel). For Spain, the debt ratio falls as higher growth boosts tax revenues. The profile shows a small kink after the spending phase comes to an end (denominator effect) but then continues to fall. 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 of the MS between 2027 and 2058 (according to GNI shares). For MS 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. Appendix G shows the assumed grants and loans receipts and repayments per MS.<sup>26</sup>

Graph 4.5. Dynamics of debt-to-GDP ratios selected countries (six year NGEU profile, high productivity)



Note: This graph reports the debt-to-GDP ratios in percentage point deviation from a no-policy change baseline. These profiles are based on scenarios in which government spending is linked to GDP. Note that these model-based debt projections can differ from the Commission's Debt Sustainability Assessment which follows a different methodology. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

<sup>24</sup> 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 the global supply chains could lead to additional inflationary pressures, which are not modelled here.

<sup>25</sup> The higher the initial debt ratio, the stronger the denominator effect on the ratio in the first year.

<sup>26</sup> These result depends on the assumed expenditure rules, as we discuss in more detail in Appendix G.



#### 4.4. CUMULATIVE MULTIPLIERS AND LONG-RUN EFFECTS

Turning to the medium and long run, we find that *cumulative* multipliers can be sizable when government capital is productive. As standard, we define cumulative multipliers as the ratio of the additional GDP and the fiscal stimulus.<sup>27</sup> Compared to government consumption, public investment can achieve a sizable long-run effect by raising productivity persistently. The cumulative multipliers, reported in Table 4.1 and Graph 4.6, are at 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.<sup>28</sup>

Table 4.1. Illustrative comparison of long-run multipliers (EU-wide)

	This paper	Ramey (2020), New-Keynesian model
Government consumption	-	0.9
Government investment (high productivity, undiscounted)	5.9	4.9 to 9.8
Government investment (low productivity, undiscounted)	3.0	2.9 to 5.4
Government investment (low productivity, discounted)	1.8	1.7 to 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 4.6. also 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.

Graph 4.6 illustrates that the dynamic medium 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.<sup>29</sup> 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 sizable growth effects remain even under more pessimistic assumptions, the changes across assumptions are noteworthy.

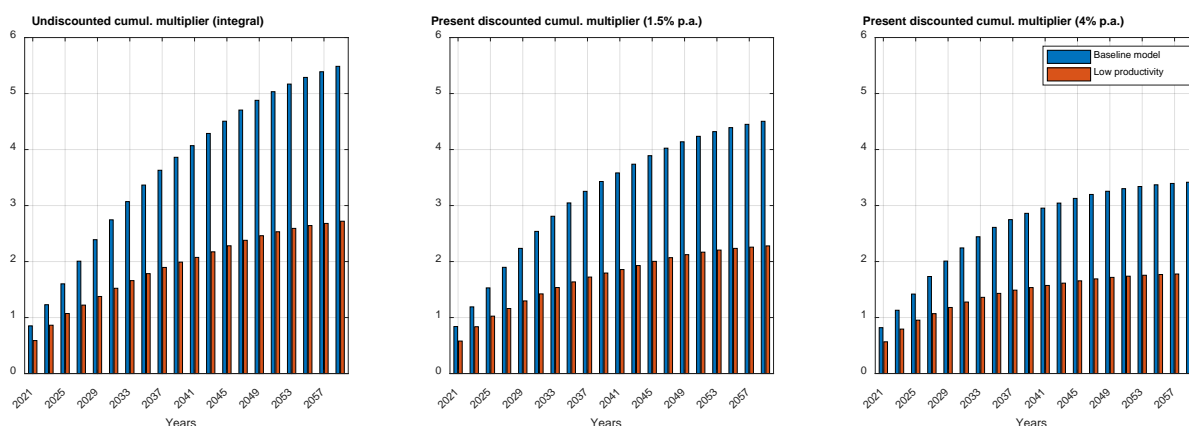
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<sup>27</sup> We include the non-additional loans in the calculations, which increase the NGEU volume but do not finance additional public investment.

<sup>28</sup> Unlike Ramey (2020), we also account for openness towards the rest-of-the world which reduces multipliers as part of the additional demand goes to foreign goods (outside the EU).

<sup>29</sup> In this case, the output elasticity of public capital is reduced from 0.12 to 0.05. This stylised (re-)calibration is in line with the lower bound considered in Leeper et al. (2010).

Graph 4.6. Dynamic cumulative multipliers (four-year NGEU profile)



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 four-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.

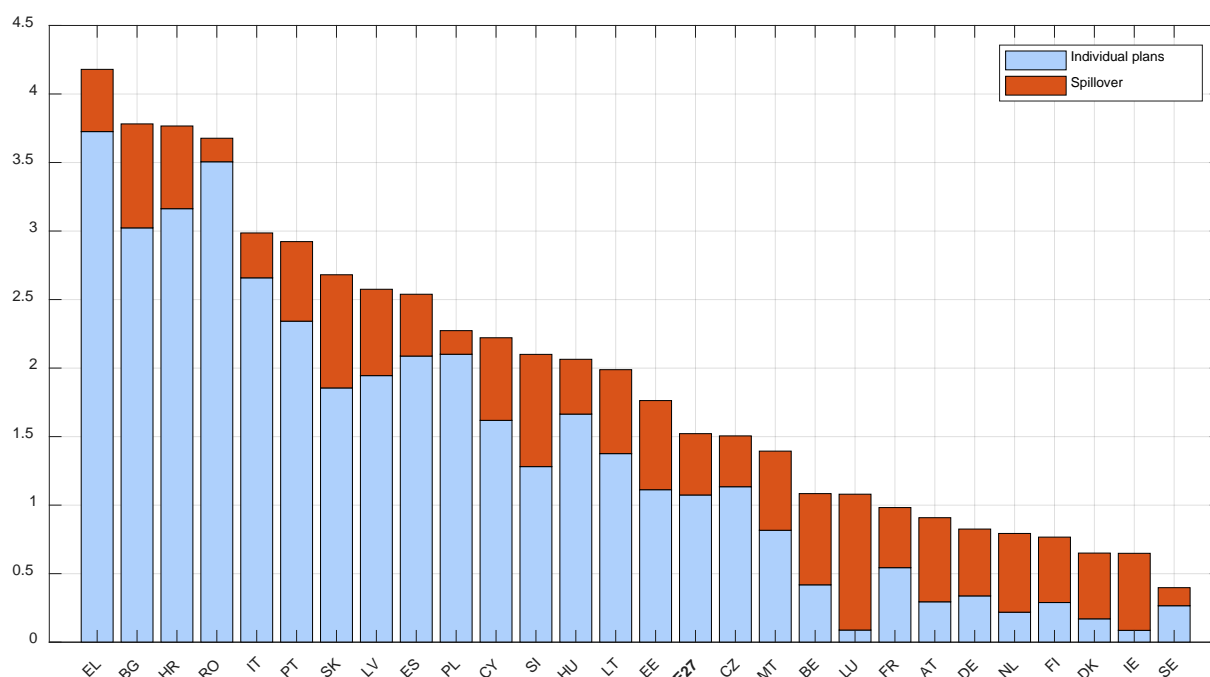
#### 4.5. A CLOSER LOOK AT COUNTRY-SPECIFIC EFFECTS

Even MS that receive a small allocation of the fund benefit significantly from spillovers from other countries' RRP. 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, e.g. LU and IE, positive spillovers explain most of the total impact. Graph 4.7a displays the peak GDP effect for all MS for a fast scenario over four years in all MS. Graph 4.7b provides results for the six-year profile. Tables 11.1 and 11.2 and Graphs 11.1 and 11.2 in Appendix F provide additional results for all MS.

Graphs 4.7a, 4.7b and 4.7c also show that NGEU strongly supports convergence. Given the allocation key, the MS with below-average GDP per capita levels are estimated to experience the largest boost to GDP levels. For a four-year stimulus and a high productivity calibration, the increase in output reaches more than 4% in Greece, around 3¾% in Bulgaria, Croatia and Romania, and around 3% in Italy and Portugal. For these countries, the role of 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 smaller for the six-year NGEU scenario (Graph 4.7b) and for the low-productivity scenario (Graph 4.7c).

Especially for MS 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 (not shown here) show that if the monetary policy in these MS partially targets the euro exchange rate, NGEU spillover becomes positive immediately.

Graph 4.7a Effects across countries (fast spending profile, high productivity)

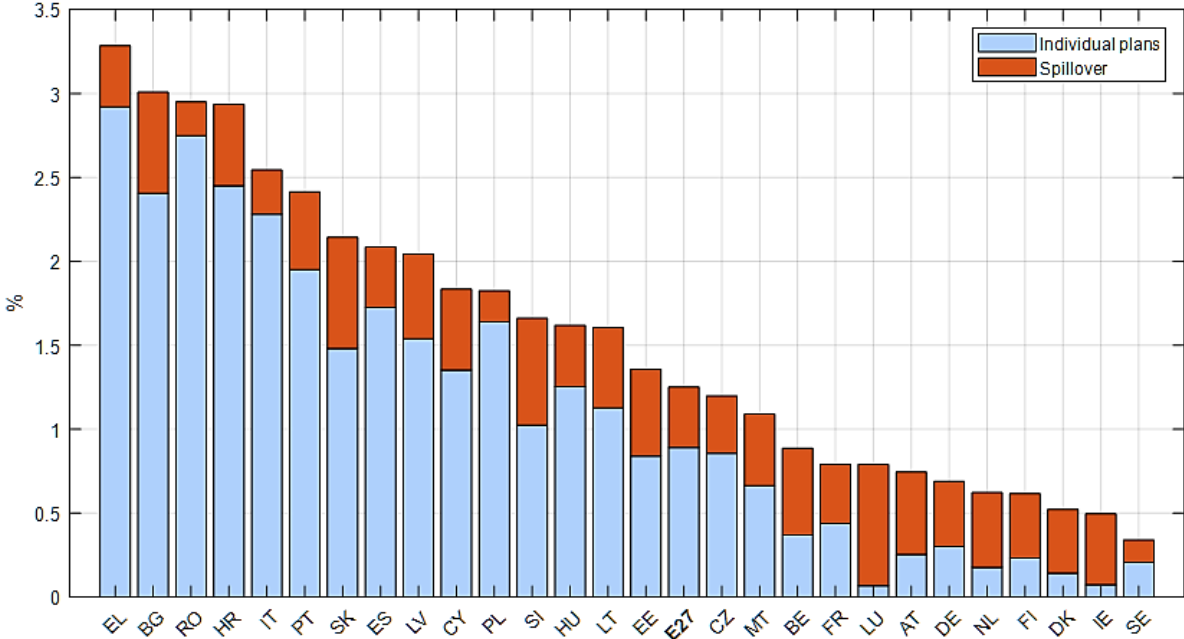


Note: This graph reports the level of real GDP in 2024 expressed in percent deviation from a no-policy change baseline and for a fast profile (even allocation across 2021 until 2024 for all Member States). Blue bars show simulation results from a simultaneous investment stimulus (NGEU). Spillover (orange) is defined as the difference of the coordinated simultaneous NGEU stimulus in all MS and the standalone 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](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Table 4.2 shows spillover effects in the peak year, i.e. the fourth year in the fast profile, for all (counterfactual) unilateral plans and for all MS, highlighting the importance of the relative NGEU allocations and bilateral trade linkages for spillover (see also the trade matrix in Appendix C). For example, the increase in investment in Belgium, which receives a relatively small allocation of NGEU funds, boosts GDP by 0.42 in Belgium, and has small spillover effects, the largest to Luxembourg (0.03). Focussing on the larger recipients of NGEU funds, the role of bilateral trade linkages becomes clearer. Greece receives a relatively large share of NGEU, which boost Greek GDP by 3.73%, but spillovers are relatively modest (the largest to Cyprus, 0.11). Spillover effects of the Spanish public investment are largest for Portugal (0.19) given the close trade linkages between the two countries. But overall, by far the largest spillover effects are coming from Italy, a large country, receiving a major share of NGEU funds. Spillovers are largest to Luxembourg and Slovenia, but also significant to Belgium, Bulgaria, Croatia, and Slovakia, among others. Note that these spillovers are often larger than what bilateral trade linkages would suggest as they are amplified by third-country effects. 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.

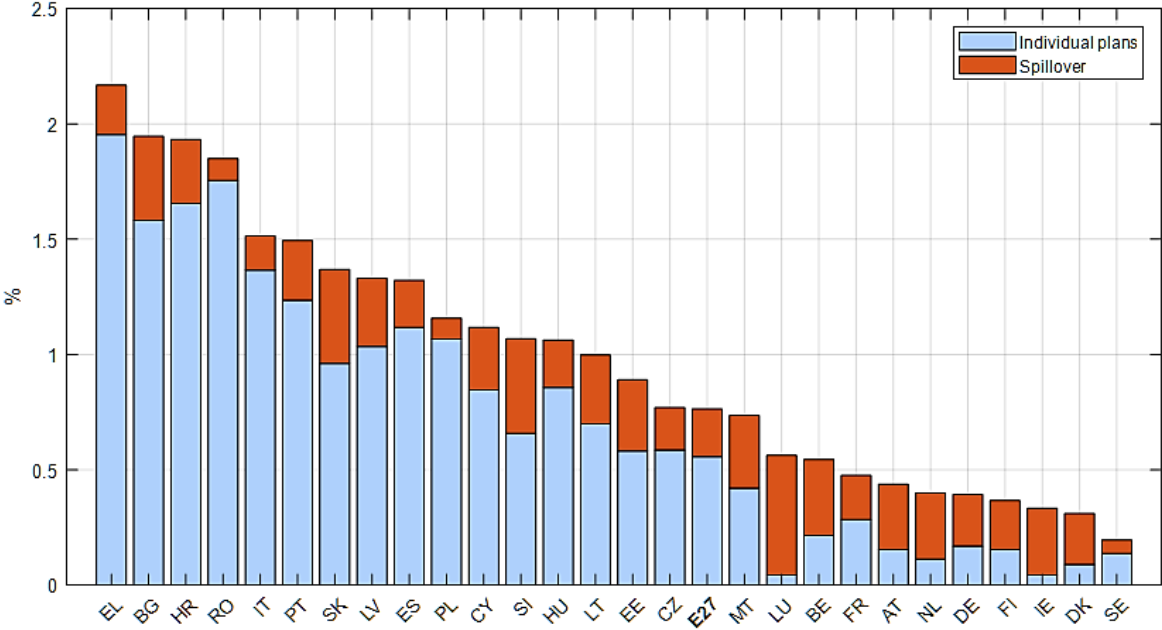
The final row shows the total effects of NGEU for each of the MS from the simulation including all NGEU spending jointly. Looking at the effects per country, one sees that the overall GDP effects for small open economies that receive a small direct allocation of funds can be considerably enlarged by the spillovers from other countries. For Belgium, the direct impact in the fourth year is 0.4, but spillovers more than double this effect to 1.1.

Graph 4.7b Effects across countries (six-year NGEU profile, high productivity)



Note: This graph reports the level of real GDP in 2026 expressed in percent deviation from a no-policy change baseline and for a six-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 MS and the standalone 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](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Graph 4.7c Effects across countries (six-year NGEU profile, low productivity)



Note: This graph reports the level of real GDP in 2026 expressed in percent deviation from a no-policy change baseline and for a fast profile (even allocation across 2021 until 2026 for all Member States) and low productivity of public capital. 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 MS and the standalone 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](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Table 4.2 Cross-country effects of (counterfactual) unilateral plans and NGEU

BE	0.42	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	3.02	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00
CZ	0.00	0.01	1.13	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.07	0.00	0.00
DK	0.00	0.00	0.00	0.17	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	0.07	0.06	0.06	0.06	0.34	0.06	0.06	0.05	0.06	0.05	0.06	0.05	0.05	0.06	0.05	0.10	0.05	0.05	0.07	0.08	0.03	0.06	0.02	0.07	0.08	0.05	0.02
EE	0.00	0.00	0.00	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
IE	0.00	0.00	0.00	0.00	0.00	0.00	0.09	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	0.04	0.10	0.01	0.03	0.03	0.03	0.04	3.73	0.03	0.03	0.03	0.03	0.11	0.03	0.03	0.05	0.01	0.06	0.04	0.03	0.01	0.03	0.01	0.04	0.04	0.03	0.00
ES	0.13	0.12	0.04	0.10	0.10	0.11	0.11	0.10	2.09	0.11	0.10	0.10	0.10	0.11	0.11	0.18	0.04	0.11	0.12	0.11	0.02	0.19	0.02	0.12	0.13	0.10	0.02
FR	0.09	0.06	0.02	0.05	0.06	0.06	0.06	0.05	0.06	0.54	0.05	0.05	0.05	0.06	0.05	0.12	0.02	0.06	0.07	0.06	0.01	0.07	0.01	0.07	0.07	0.05	0.01
HR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.16	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.09	0.01	0.00	0.00
IT	0.30	0.28	0.09	0.21	0.23	0.25	0.25	0.23	0.24	0.23	0.28	2.66	0.23	0.24	0.23	0.46	0.10	0.26	0.26	0.27	0.06	0.24	0.09	0.35	0.29	0.22	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	1.62	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	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.95	0.04	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	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	1.38	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	0.09	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	1.66	0.00	0.00	0.02	0.01	0.00	0.02	0.02	0.05	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	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NL	0.02	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	0.02	0.00	0.01	0.22	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00
AT	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.29	0.00	0.01	0.00	0.02	0.01	0.01	0.00
PL	0.02	0.02	0.07	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.06	0.02	0.05	0.01	0.02	0.02	2.10	0.00	0.02	0.03	0.08	0.01	0.02
PT	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.01	0.03	0.03	0.02	0.00	2.34	0.00	0.02	0.03	0.02	0.00
RO	0.01	0.09	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	0.08	0.01	0.01	0.02	0.02	0.00	3.51	0.03	0.04	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	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	1.28	0.01	0.00	0.00
SK	0.01	0.01	0.05	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	0.01	0.01	0.02	1.86	0.01	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	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	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	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.27
NGEU	1.07	3.76	1.50	0.64	0.82	1.75	0.63	4.15	2.53	0.97	3.75	2.97	2.20	2.56	1.97	1.06	2.06	1.38	0.79	0.90	2.26	2.91	3.66	2.09	2.66	0.76	0.39
	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

Note: This table displays cross-country GDP effects after 4 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 entail increase Belgian GDP by 0.07%, 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](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 nonlinearities.

## 5. 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 programme – a key aspect of the policy debate.

We find that the positive macroeconomic spillovers of NGEU are significant. Quantitatively, EU-wide GDP effects of NGEU could be around one third larger when explicitly accounting for positive spillover effects. Moreover, in some cases such as Luxemburg and Ireland, spillover effects explain most of the domestic GDP gains. A simple aggregation of individual effects of the MS's plans would thus substantially underestimate the growth effects of NGEU.

For the sake of clarity, our analysis has abstracted from some relevant factors. First, reforms are a central element of NGEU alongside investment. Reforms can support medium-run and long-run growth by many channels, in particular by increasing labour market participation, improving market and framework conditions that strengthen investment in the broad sense. Yet, it remains beyond the scope of this paper to model the multitude of concrete reform efforts and market outcomes included in Member States' Recovery and Resilience plans.<sup>30</sup> Second, NGEU generates additional fiscal space. Especially the grant instruments reduce the debt-to-GDP ratio in highly indebted countries. This channel can reduce risk premia, also for the banking sector, and stimulate private consumption and investment. Third, we have abstracted from any details of the country-specific investment and reform plans. We leave these important topics for future research.

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<sup>30</sup> For an analysis on the potential growth impact of reforms, see, for example, Varga and in 't Veld (2014).

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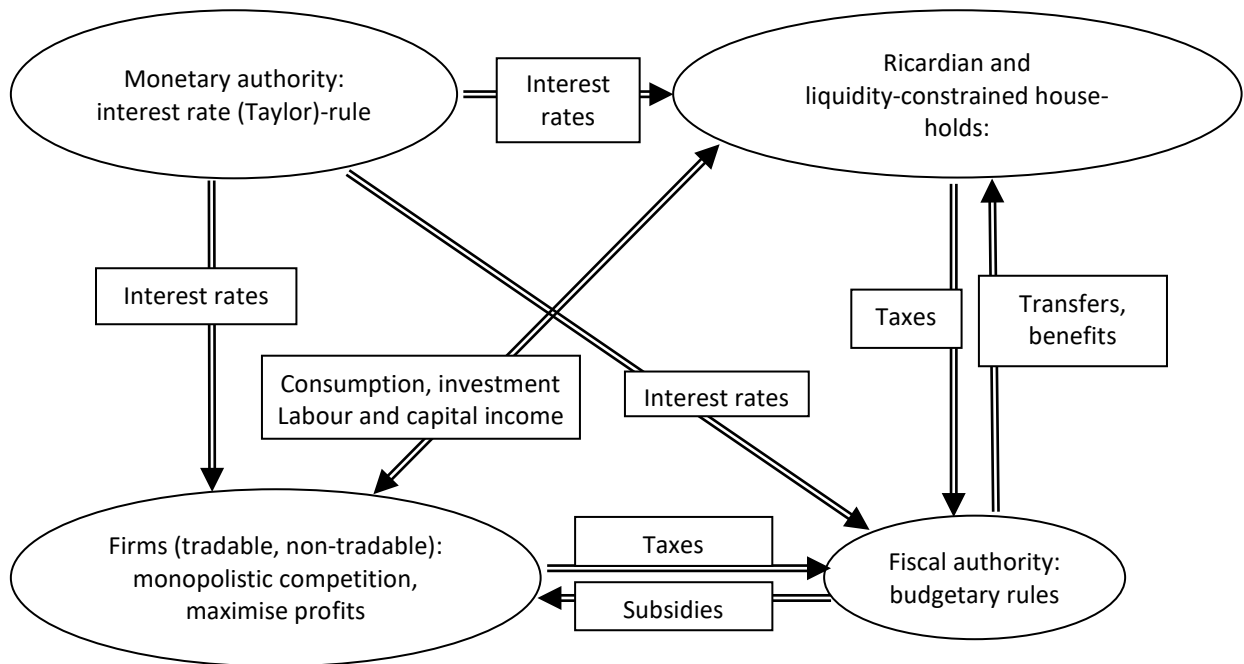
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## 6. APPENDIX A: MODEL OVERVIEW

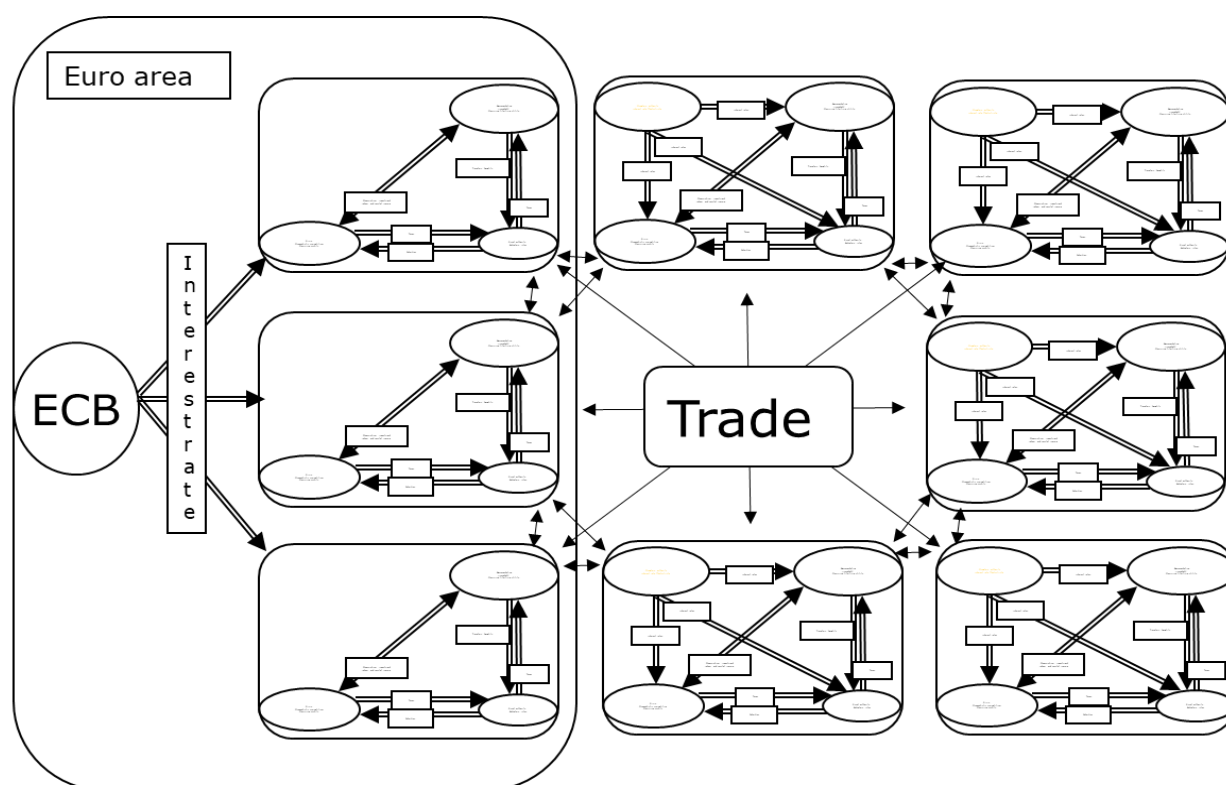
Graph 6.1. Basic structure of QUEST model regions



Source: Commission services.

The model underlying the discussion in this paper is of this type and includes 28 isomorphic geographical regions (all EU Member States and the rest-of-the world). Graph 6.1 sketches the basic structure of the regional blocks and Graph 6.2 shows the interlinked regional blocks with trade. As shown below, for euro area countries the European Central Bank (ECB) sets the monetary policy.

Graph 6.2. Multicountry structure of QUEST model regions



Source: Commission services.

## 7. APPENDIX B: MODEL derivation

This Appendix describes the firm, household, government sectors and international linkages for a single region. To simplify notation, apart from the discussion of trade linkages, we do not explicitly distinguish country indices since all regions are isomorphic.

### 7.1. PRODUCTION

Each region is home to a tradable sector, a non-tradable sector.

#### Tradable and non-tradable production

The model consists of a continuum of firms  $j$  operating in the tradable (T) and non-tradable (NT) sectors. Each firm  $j$  produces a variety of the T or NT good that is an imperfect substitute for varieties produced by other firms. Sectoral output  $O_t^J$  with  $J \in \{T, NT\}$  is a CES aggregate of the varieties  $O_t^{j,J}$ :

$$O_t^J \equiv \left( \int_0^1 (O_t^{j,J})^{(\sigma_J-1)/\sigma_J} dj \right)^{\sigma_J/(\sigma_J-1)} \quad 7.1$$

where  $\sigma_j$  is the elasticity of substitution between varieties  $j$  in sector  $J$ . The elasticity value can differ between T and NT, implying sector-specific price mark-ups.

The firms in sector T sell consumption and investment goods and intermediate inputs to domestic and foreign private households and firms and consumption and investment goods to domestic and foreign governments. The NT sector sells consumption goods to the domestic households, consumption and investment goods to the domestic government, and intermediate inputs to domestic firms. Hence, all private investment in physical capital consists of T goods.

Output is produced with a CES technology that combines value-added ( $Y_t^j$ ) and intermediate inputs ( $INT_t^j$ ). It nests a Cobb-Douglas technology with capital ( $K_t^j$ ), production workers ( $L_t^j$ )<sup>31</sup> and public capital ( $KG_t$ ) for the production of  $Y_t^j$ :

$$O_t^j = \left( (1 - s_{in}^j)^{\frac{1}{\sigma_{in}}} (Y_t^j)^{(\sigma_{in}-1)/\sigma_{in}} + (s_{in}^j)^{\frac{1}{\sigma_{in}}} (INT_t^j)^{(\sigma_{in}-1)/\sigma_{in}} \right)^{\sigma_{in}/(\sigma_{in}-1)} \quad 7.2$$

$$Y_t^j = A_t^j (u_t^j K_t^j)^{1-\alpha} (L_t^j)^\alpha (KG_t)^{\alpha_g} \quad 7.3$$

where  $s_{in}^j$  and  $\sigma_{in}$  are, respectively, the steady-state share of intermediates in output and the elasticity of substitution between intermediates and value-added, and  $A_t^j$  and  $u_t^j$ , are total factor productivity (TFP) and capacity utilisation, respectively.<sup>32</sup> Firm-level employment  $L_t^j$  is a CES aggregate of the labour services supplied by individual households  $i$ :

$$L_t^j \equiv \left( \int_0^1 (L_t^{i,j})^{(\theta-1)/\theta} di \right)^{\theta/(\theta-1)} \quad 7.4$$

where  $\theta$  indicates the degree of substitutability between the different types of labour  $i$ .

The objective of the firm is to maximise the present value of current and future expected real profits ( $Pr_t^j$ ) relative to the sectoral price level:

$$Pr_t^j = \frac{p_t^j}{p_t} O_t^j - \frac{p_t^{INT,j}}{p_t} INT_t^j - (1 + ssc_t^j) \frac{w_t^p}{p_t} L_t^j - i_t^j \frac{p_t^I}{p_t} K_t^j - adj_t^j \quad 7.5$$

---

<sup>31</sup> Our calibration allows for a fraction of overhead labour and fixed costs.

<sup>32</sup> Lower case letters denote ratios and rates. In particular,  $p_t^j \equiv P_t^j/P_t$  is the price of good  $j$  relative to the GDP deflator,  $w_t \equiv W_t/P_t$  is the real wage,  $u_t^j$  is actual relative to steady-state (full) capital utilisation.

where  $ssc_t^j$ ,  $w_t^p$ ,  $i_t^j$  and  $p_t^j$  are the employer social security contributions, the private-sector real wage, the rental rate of capital, and the price of capital. The firms face technology and regulatory constraints that restrict their capacity to adjust.  $adj_t^j = adj_t^{L,j} + adj_t^{P,j} + adj_t^{u,j}$  summarises adjustment costs for labour ( $adj_t^{L,j}$ ), prices ( $adj_t^{P,j}$ ) and capacity utilisation ( $adj_t^{u,j}$ ) follow convex functional forms.

$$adj_t^{L,j} \equiv 0.5\gamma_L w_t^p (\Delta L_t^j)^2 \quad 7.6$$

$$adj_t^{P,j} \equiv 0.5\gamma_P (\pi_t^j)^2 P_{t-1}^j O_t^j \text{ with } \pi_t^j \equiv P_t^j / P_{t-1}^j - 1 \quad 7.7$$

$$adj_t^{u,j} \equiv \left( \gamma_{u,1} (u_t^j - 1) + \frac{\gamma_{u,2}}{2} (u_t^j - 1)^2 \right) \frac{p_t^j}{p_t} K_t^j \quad 7.8$$

**Optimality.** The firms choose labour input, capital services, capacity utilisation, the price of output  $j$ , and the volume of output  $j$  given the demand function for  $O_t^j$ , the production technology (7.2) and (7.3), and the adjustment costs (7.6-7.8). The first-order conditions (FOC) are:

$$\frac{\partial Pr_t^j}{\partial L_t^j} \Rightarrow \frac{\partial O_t^j}{\partial L_t^j} \eta_t^j - \gamma_L w_t^p \Delta L_t^j + \gamma_L \beta E_t (\lambda_{t+1}^r / \lambda_t^r w_{t+1}^p \Delta L_{t+1}^j) = (1 + ssc_t^j) w_t^p \quad 7.9$$

$$\frac{\partial Pr_t^j}{\partial K_t^j} \Rightarrow \frac{\partial O_t^j}{\partial K_t^j} \eta_t^j = i_t^j p_t^j \quad 7.10$$

$$\frac{\partial Pr_t^j}{\partial u_t^j} \Rightarrow \frac{\partial O_t^j}{\partial u_t^j} \eta_t^j = p_t^j K_t^j (\gamma_{u,1} + \gamma_{u,2} (u_t^j - 1)) \quad 7.11$$

$$\frac{\partial Pr_t^j}{\partial p_t^j} \Rightarrow \eta_t^j = 1 - \frac{1}{\sigma^j} - \frac{\gamma_P}{\sigma^j} \left( \beta E_t \left( \frac{\lambda_{t+1}^r}{\lambda_t^r} \frac{O_{t+1}^j}{O_t^j} \pi_{t+1}^j \right) - \pi_t^j \right) \quad 7.12$$

where  $\eta_t^j$  is the Lagrange multiplier associated with the production technology,  $\beta$  is the discount factor of Ricardian households (see below) that are the firm owners,  $\lambda_t^r$  is their marginal value of wealth in terms of consumption as defined in (7.20) below.

Equation (7.9) implies that optimising firms equate the marginal product of labour net of adjustment costs to wage costs. The equations (7.10-7.11) jointly determine the optimal capital stock and capacity utilisation by equating the marginal value product of capital to the rental price and the marginal product of capital services to the marginal cost of increasing capacity. Equation (7.12) defines the price mark-up factor as function of the elasticity of substitution and price adjustment costs. QUEST follows the empirical literature and allows for backward-looking elements in price setting by assuming that the fraction  $1-sfp$  of firms indexes prices to past inflation, which leads to the specification:

$$\eta_t^j = \frac{\sigma^j - 1}{\sigma^j} - \frac{\gamma_P}{\sigma^j} \left( \beta E_t \left( \frac{\lambda_{t+1}^r}{\lambda_t^r} \frac{O_{t+1}^j}{O_t^j} (sfp^j E_t \pi_{t+1}^j + (1 - sfp^j) \pi_{t-1}^j) \right) - \pi_t^j \right) \text{ with } 0 \leq sfp \leq 1 \quad 7.13$$

for the inverse of the price mark-ups in the T and NT sectors. Given the symmetry of objectives and constraints across firms  $j$  in sector  $J$ , the superscript  $j$  for individual firms can be dropped to obtain aggregate sectoral equations for T and NT. The price setting decision establishes a link between output and prices in the economy. For constant technology, factor demand and/or capacity utilisation increase (decline) with increasing (declining) demand for output, which leads to an increase (decline) in factor and production costs and, hence, an increase (decline) in the price level of domestic output.

## 7.2. HOUSEHOLDS

The household sector consists of a continuum of households  $h \in [0,1]$ , partitioned in two groups. A share  $s^l \leq 1$  is liquidity-constrained (indexed by  $l$ ). These households do not participate in financial markets. Instead, they consume their entire disposable wage and transfer income in each period. The remaining fraction  $(1 - s^l)$  are Ricardian with full access to financial markets (indexed by  $r$ ). Period utility is separable in consumption ( $C_t^h$ ), leisure ( $1 - L_t^i$ ). We also allow for (exogenous) habit persistence in consumption ( $h^c$ ). Period utility is hence determined as:

$$U(C_t^h, 1 - L_t^h) = (1 - h^c) \log(C_t^h - h^c \bar{C}_{t-1}^h) + \omega \frac{(1 - L_t^i)^{1-\kappa}}{1 - \kappa} \quad 7.14$$

where  $\kappa > 0$ . Households supply differentiated types of labour services  $i$ , which are distributed equally over household types.<sup>33</sup> Unions bundle the differentiated labour services and maximise a joint utility function for each type of labour  $I$  (see below).

### 7.2.1 Ricardian households

Ricardian households have full access to financial markets and own all domestic firms. They hold domestic government bonds ( $B_t^G$ ) and bonds issued by other domestic and foreign households ( $B_t^r, B_t^{F,r}$ ) and capital ( $K_t^J$ ) of both sectors. The household receives income from labour (net of adjustment costs on wages), financial assets, rental income from lending capital to firms, and profit income. The unemployed ( $1 - L_t$ ) receive benefits  $ben_t = benrrW_t$ , where  $benrr$  is the exogenous benefit replacement rate, and  $W_t$  wage level. In addition, there is income from general transfers,  $TR_t$ . Income from labour corporate profits are taxed at rates  $t_t^w$  and  $t_t^k$ , respectively. Finally, households pay lump-sum taxes,  $T_t^{LS}$ . The per-period budget constraint in real terms is given by:

$$\begin{aligned} (1 + t_t^c) p_t^c C_t^r + \sum_{J=T,NT} p_t^l I_t^J + (B_t^G + B_t^r) + rer_t B_t^{F,r} + T_t^{LS,r} - (1 - t_t^k) \sum_{J=T,NT} (i_t^J p_t^l K_t^J + p_t^l P r_t^J) \\ - (1 + r_{t-1})(B_{t-1}^G + B_{t-1}^r) - (1 + r_{t-1}^F) rer_t B_{t-1}^{F,r} - (1 - t_t^w) w_t^i L_t^i - ben_t^{real} (1 - L_t^i) - TR_t^{real} \\ + \sum_{J=T,NT} (adj_t^{K,J} + adj_t^{l,J}) + adj_t^{w,r}, \end{aligned} \quad 7.15$$

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<sup>33</sup> The aggregate value of any household-specific variable  $X_t^h$  in per-capita terms is given by  $X_t \equiv \int_0^1 X_t^h dh = (1 - s^l) X_t^r + s^l X_t^l$ .

With the following adjustment costs specifications:

$$adj_t^{K,J} \equiv 0.5\gamma_{K,J}(I_t^J/K_{t-1}^J - \delta^{K,J})^2 p_t^I \bar{K}_{t-1}^J \quad 7.16$$

where  $p_t^C$  and  $p_t^I$  are the price deflators for consumption and investment relative to the GDP deflator,

$$adj_t^{I,J} \equiv 0.5\gamma_{I,J} p_t^I (\Delta I_t^J)^2 \quad 7.17$$

$$adj_t^{w,r} \equiv 0.5\gamma_W (\pi_t^{w,i})^2 \bar{L}_t^p, \quad 7.18$$

respectively.

The FOCs of the optimisation problem provide the intertemporal consumption rule, where the ratio of the marginal utility of consumption in periods  $t$  and  $t+1$  is equated to the real interest rate adjusted for the rate of time preference:

$$E_t(\lambda_t^r / \lambda_{t+1}^r) = \beta(1 + r_t) \quad 7.19$$

$$\lambda_t^r = \frac{(1-h^c)^{\sigma_c}}{(1+t_t^c) p_t^C (C_t^r - h^c C_{t-1}^r)^{\sigma_c}} \quad 7.20$$

with the real interest rate  $r_t = i_t - E_t \pi_{t+1}$ , i.e. the nominal rate minus the expected per-cent change in the GDP deflator.

The FOC for investment provides an investment rule linking capital formation to the shadow price of capital:

$$\gamma_{K,J} \left( \frac{I_t^J}{K_{t-1}^J} - \delta^{K,J} \right) + \gamma_{I,J} \Delta I_t^J - \gamma_{I,J} \beta E_t \left( \frac{\lambda_{t+1}^r p_{t+1}^I}{\lambda_t^r p_t^I} \Delta I_{t+1}^J \right) = q_t^J - 1 \quad 7.21$$

and  $q_t^J \equiv \frac{\xi_t^J}{p_t^I}$  corresponds to the present discounted value of rental income from physical capital, which follows from the FOC w.r.t. the stock of capital:

$$q_t^J = i_t^J + \beta E_t \left( \frac{\lambda_{t+1}^r p_{t+1}^I}{\lambda_t^r p_t^I} \left[ t_{t+1}^k \delta^{K,J} - \gamma_K \left( \frac{I_{t+1}^J}{K_t^J} - \delta^{K,J} \right) \frac{I_{t+1}^J}{K_t^J} + (1 - \delta^{K,J}) q_{t+1}^J \right] \right) \quad 7.22$$

The FOC for investment in foreign bonds together with equation (7.19) and the approximation  $\ln(1+x) \approx x$  for small values of  $x$  gives the UIP condition:

$$i_t = i_t^F + E_t \frac{\Delta e_{t+1}}{e_t} + \varepsilon_t^{rBF} \quad 7.23$$

that determines the nominal exchange rate vis-à-vis the RoW. There are no capital controls that would insulate domestic from international capital markets and separate domestic monetary from exchange rate policy. Equation (7.23) contains an endogenous external risk premium  $\varepsilon_t^{rBF} = -\alpha \left( \frac{e_t B_t^{F,r}}{4Y_t} - \right.$



$\frac{B^{F,tar}}{4\bar{Y}}$ ) that depends on the net foreign asset (NFA) position ( $B_t^{F,r}$ ) of the domestic economy relative to the target value. An increase (decline) in the NFA position of the domestic economy increases (reduces) the risk on foreign relative to domestic bonds. The endogenous NFA risk premium rules out explosive NFA dynamics and closes the external side of the model as shown by Schmitt-Grohé and Uribe (2003). In particular, a deterioration of the domestic NFA position increases domestic financing costs and dampens interest-sensitive domestic consumption and investment demand.

### 7.2.2 Liquidity-constrained households

Liquidity-constrained households consume their entire disposable income at each date. Real consumption of household  $l$  is thus determined by the net wage, benefit and transfer income minus the lump-sum tax:

$$(1 + t_t^c)P_t^c C_t^l = (1 - t_t^w)W_t L_t^l + TR_t + ben_t(1 - L_t^l) - T_t^{LS}. \quad 7.24$$

### 7.2.3 Wage setting

Aggregate labour input is a CES aggregate of differentiated labour services  $i$  supplied by the individual households:

$$L_t = \left( \int_0^1 L_t^i \frac{\theta-1}{\theta} di \right)^{\frac{\theta}{\theta-1}} \quad 7.25$$

with  $\theta$  being the elasticity of substitution between labour varieties  $i$ , which provides the demand function for differentiated labour services,  $L_t^i = (W_t^i/W_t)^{-\theta} L_t$ .

A trade union maximises a joint utility function for each type of labour  $i$  in the private sector and the government sector. It is assumed that types of labour are distributed equally over household types with their respective population weights. The trade union sets wages by maximising a weighted average of the utility functions of both households. The sectoral wage rules with symmetry in the behaviour between types of labour  $i$  are:

$$(mrs_t)^{1-wrlag} \left( \frac{\frac{W_{t-1}}{P_{t-1}^c}}{(1 - t_t^w) \frac{\theta-1}{\theta} - benrr} \right)^{wrlag} = \frac{\frac{\theta-1}{\theta} (1 - t_t^w) W_t - ben_t}{P_t^c} \quad 7.26$$

$$+ \frac{\gamma^w}{\theta} (1 + \pi_t^w) \pi_t^w - \beta E_t \left( \frac{\lambda_{t+1}^{av}}{\lambda_t^{av}} \frac{\gamma^w}{\theta} (1 + \pi_{t+1}^w) \frac{L_{t+1}}{L_t} (sfw \pi_{t+1}^w + (1 - sfw) \pi_{t-1}^w) \right)$$

Where  $mrs_t$  denotes the marginal rate of substitution (weighted average across household types),  $\lambda_t^{av} \equiv s^r \lambda_t^r + s^l \lambda_t^l$ ,  $benrr$  is the benefit replacement rate, and  $ben_t$  are benefits. The wage rule allows for (ad hoc) real wage rigidity ( $wrlag$ ) in the spirit of Blanchard and Galí (2007). In the presence of wage stickiness, the fraction  $1-sfw$  of workers ( $0 \leq sfw \leq 1$ ) forms expectations of future wage growth on the basis of wage inflation in the previous period.

### 7.3. FISCAL POLICY

#### 7.3.1 Public investment: Time-to-build and time-to-spend.

We model public investment with time-to-build and time-to-spend delays for public investment along the lines of Leeper *et al.* (2010).<sup>34</sup> Formally, public capital follows the law of motion:

$$K_t^G = (1 - \delta^g)K_{t-1}^G + A_{t-N}^{IG}, \quad 7.27$$

where  $A_{t-N}^{IG}$  denotes authorised investment and  $\delta^g$  the depreciation rate of public capital.<sup>35</sup> Time-to-spend delays (Ramey, 2020) induce lags between authorised investment (appropriations) and implemented government investment following

$$I_t^G = \sum_{n=0}^N \psi_n A_{t-n}^{IG}, \quad 7.28$$

where the parameters  $\psi_n$ , with  $n \in \{0, \dots, N\}$ , govern the fraction of authorised outlays implemented investment in each period. With this feature, authorised investment only gradually leads to higher (public) investment demand. Our simulations use  $N = 4$  (one year in the quarterly model).

#### 7.3.2 The national government budget

We assume that government purchases ( $G_t$ ), and nominal transfers ( $TR_t$ ) correspond to constant shares of nominal GDP. The government receives consumption, labour, corporate and lump-sum tax revenue, and employer social security contributions. Real government debt incl. RRF loans ( $B_t^G$ ) evolves according to:

$$\begin{aligned} B_t^G = & (1 + i_t^g - \pi_t)B_{t-1}^G + p_t^C(G_t + IG_t) + ben_t^{real}(1 - L_t) + TR_t^{real} - T_t^{LS} \\ & - \sum_J [t_t^k(i_t^J p_t^J K_t^J + p_t^J Pr_t^J) + (t_t^w + ssc_t^J)w_t L_t^J] - t_t^C p_t^C C_t \\ & + CO_t^{EU} - GR_t^{EU} + \omega^{EU} r_{t-1}^{g,EU} B_{t-1}^{G,EU} \end{aligned} \quad 7.29$$

where  $i_t^g = \rho_{ig} i_{t-1}^g + (1 - \rho_{ig})i_t$  accounts for a gradual pass through of policy rates into effective government financing costs associated with the maturity structure of government debt. Receiving a grant ( $GR_t^{EU}$ ) decreases national government debt. In the long run, we assume that lump-sum contributions ( $CO_t^{EU}$ ) finance the EU budget. The term  $r_{t-1}^{g,EU} B_{t-1}^{G,EU}$  captures contributions to interest rate payments of EU debt (see below), weighed by the country's GDP share in the EU ( $\omega^{EU} = \frac{size^n}{size^{EU}}$  for each MS  $n$ ).

The lump-sum tax stabilises the debt-to-GDP ratio:

$$\Delta T_t^{LS} = \tau^B (B_t^G / (4Y_t) - \overline{btar}) + \tau^{def} \Delta B_t^G \quad 7.30$$

<sup>34</sup> In particular, the standard model corresponds to Baxter and King (1993). For private investment, we maintain the standard assumptions with no additional time lags.

<sup>35</sup> The simulations below consider  $N = 4$  (one year in the quarterly model). While some projects will require longer time-to-build lags, other investment can be considered as maintenance enhancing productivity earlier. Nonetheless, they remain persistent as public capital depreciates only slowly.  $N = 0$  nests the standard model.

with  $\overline{btar}$  being the target level of government debt-to-GDP. The consumption, corporate income and personal income tax rates and the rate of employer social security contributions are exogenous.

In terms of modelling, grants and loans have different implications for net foreign assets and government debt. Receiving a grant decreases government debt and increases net foreign assets. By contrast, loans increase debt. These back-to-back loans will be repaid gradually over 30 years by the beneficiary MS.

### 7.3.3 The EU budget

The budget includes grants, loans and contributions by the MS. The EU debt in real terms follows

$$B_t^{G,EU} = \sum_{n=1}^{27} (GR_t^{n,EU} - CO_t^{n,EU}) \frac{size^n}{size^{EU}} \quad 7.31$$

where  $\sum_{n=1}^{27} GR_t^{n,EU} - CO_t^{n,EU}$  aggregates (weighted by the relative size,  $\frac{size^n}{size^{EU}}$ ) grant allocations and contributions for all MS. Interest payments are covered by the MS' governments.

### 7.3.4 Monetary policy

Monetary policy in each currency area follows a Taylor rule that allows for a smoothing of the interest rate response to inflation and the output gap:

$$i_t = \rho_i^R i_{t-1} + (1 - \rho_i^R) \left( \bar{r} + \pi^{tar} + \tau_\pi \left( \frac{\pi_{t,yoy}^C}{4} - \pi^{tar} \right) + \tau_y ygap_t \right), \quad 7.32$$

The central bank has an inflation target  $\pi^{tar}$ , adjusts its policy rate relative to the steady-state value  $\bar{r}$  when actual CPI inflation deviates from the target, where  $\pi_{t,yoy}^C \equiv P_t^C / P_{t-4}^C - 1$  is year-on-year CPI inflation, or output deviates from its potential level, i.e. a non-zero output gap ( $ygap_t$ ). The output gap is defined as deviation of factor utilisation from its long-run trend.<sup>36</sup> We account for accommodative monetary policy at the ZLB by allowing for regime-dependent interest rate smoothing  $\rho_i^R$  with  $R = \{NoZLB, ZLB\}$ . Our simulations (exogenously) assume that the interest rate is accommodative for six quarters, i.e.  $\rho_i^R = \rho_i^{ZLB}$  for 2021Q1:2022Q2 and  $\rho_i^R = \rho_i^{NoZLB}$  otherwise.

In the euro area,  $\pi_{t,yoy}^C$  and  $ygap_t$  are union-wide (GDP-weighted) averages. For MS participating in the ERMII, we include an exchange rate target in the Taylor rule (7.32).

## 7.4. TRADE LINKAGES

At the heart of our spillover analysis is a rich trade structure linking the individual economies. In this setup, we assume that private households and the government have identical preferences across goods.

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<sup>36</sup> We define  $ygap_t = \alpha \ln\left(\frac{L_t}{L_t^{SS}}\right) + (1 - \alpha) \ln\left(\sum_j \frac{y_t^j}{Y_t} \frac{ucap_t^j}{ucap_t^{SS,j}}\right)$ , where  $L_t^{SS}$  and  $ucap_t^{SS}$  are moving averages of employment and capacity utilisation rates.

Let  $Z = C + G + IG$  be the demand by private households and the government with preferences for T and NT goods following CES functions:

$$Z_t = \left( (1 - s^T)^{1/\sigma_{tnt}} (Z_t^{NT})^{(\sigma_{tnt}-1)/\sigma_{tnt}} + (s^T)^{1/\sigma_{tnt}} (Z_t^T)^{(\sigma_{tnt}-1)/\sigma_{tnt}} \right)^{\sigma_{tnt}/(\sigma_{tnt}-1)} \quad 7.33$$

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 ( $Z_t^{T,M}$ ) T goods:

$$Z_t^T = \left( (1 - s_m)^{1/\sigma_x} (Z_t^{T,D})^{(\sigma_x-1)/\sigma_x} + s_m^{1/\sigma_x} (M_t^Z)^{(\sigma_x-1)/\sigma_x} \right)^{\sigma_x/(\sigma_x-1)} \quad 7.34$$

The elasticity of substitution between the bundles of NT versus T goods is  $\sigma_{tnt}$ . The elasticity of substitution between the bundles of domestically produced versus imported T goods is  $\sigma_x$ . The steady-state shares of T goods in  $Z_t$  and imports in  $Z_t^T$  are  $s^T$  and  $s_m$ , respectively.

All private investment in physical capital in the  $J \in \{T, NT\}$  sectors consists of T goods:<sup>37</sup>

$$I_t^J = \left( (1 - s_m)^{1/\sigma_x} (I_t^{J,T,D})^{(\sigma_x-1)/\sigma_x} + s_m^{1/\sigma_x} (M_t^{J,J})^{(\sigma_x-1)/\sigma_x} \right)^{\sigma_x/(\sigma_x-1)}, \quad 7.35$$

The CES aggregate (7.33) combining T and NT goods gives the following demand functions:

$$Z_t^T = s^T (P_t^T/P_t^C)^{-\sigma_{tnt}} (C_t + G_t + IG_t), \quad 7.36$$

$$Z_t^{NT} = (1 - s^T) (P_t^{NT}/P_t^C)^{-\sigma_{tnt}} (C_t + G_t + IG_t), \quad 7.37$$

The intermediate inputs in sector  $J \in \{T, NT\}$  are also composites of T and NT analogously to equations (7.33) and (7.34), with T being domestically produced or imported:

$$INT_t^J = \left( (1 - s_{int}^J)^{1/\sigma_{tnt}} (INT_t^{NT,J})^{(\sigma_{tnt}-1)/\sigma_{tnt}} + (s_{int}^J)^{1/\sigma_{tnt}} (INT_t^{T,J})^{(\sigma_{tnt}-1)/\sigma_{tnt}} \right)^{\frac{\sigma_{tnt}}{\sigma_{tnt}-1}} \quad 7.38$$

$$INT_t^{T,J} = \left( (1 - s_m)^{1/\sigma_x} (INT_t^{T,D,J})^{(\sigma_x-1)/\sigma_x} + s_m^{1/\sigma_x} (M_t^{INT,J})^{(\sigma_x-1)/\sigma_x} \right)^{\frac{\sigma_x}{\sigma_x-1}}. \quad 7.39$$

This gives demand functions for T and NT intermediates analogously to (7.36 and 7.37):

$$INT_t^{T,J} = s_{int}^J (P_t^T/P_t^{INT,J})^{-\sigma_{tnt}} INT_t^J \quad 7.40$$

$$INT_t^{NT,J} = (1 - s_{int}^J) (P_t^{NT}/P_t^{INT,J})^{-\sigma_{tnt}} INT_t^J \quad 7.41$$

The price index for the bundle of tradable goods for each demand category  $H_t^T$  is:

$$P_t^{T,H} = \left( (1 - s_m) (P_t^{T,D})^{1-\sigma_x} + s_m (P_t^M)^{1-\sigma_x} \right)^{1/(1-\sigma_x)} \quad 7.42$$

Import demand by demand components is:

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<sup>37</sup> The assumption of all investment goods being composed of tradable investment is a simplification, but accounts for the observation that the content in tradable goods and imports is substantially higher for private investment compared to consumption goods, including less demand for non-tradable services in the distribution (e.g. Bems 2009, Burstein et al. 2004). Note also that tradable goods production also uses non-tradable intermediate goods, so that non-tradable goods and prices enter indirectly also the production of investment goods.

$$M_t^H = s_m H_t^T. \quad 7.43$$

Total imports are the sum of imports by component:

$$M_t = \sum_H M_t^H \quad 7.44$$

Total imports are a CES bundle of bilateral imports from foreign regions  $f$ :

$$M_t = \left( \sum_f (s^f)^{\frac{1}{\sigma_1}} M_t^f \frac{\sigma_1 - 1}{\sigma_1} \right)^{\frac{\sigma_1}{\sigma_1 - 1}} \quad 7.45$$

where  $\sigma_1$  is the elasticity of substitution between imports of different origins,  $s^f$  is the steady-state share of region  $f$  in the domestic economy's imports. The demand for goods from region  $f$  is given by:

$$M_t^f = s^f \left( \frac{P_t^{M,f}}{P_t^M} \right)^{-\sigma_1} M_t. \quad 7.46$$

Exporters sell domestically produced tradable goods in world markets. Prices for exports and imports are set by domestic and foreign exporters respectively. The exporters in each region buy goods from their respective domestic producers and sell them in foreign markets. They transform domestic goods into exportables using a linear technology. Prices are sticky in the currency of the importer, so that pass-through of nominal exchange rate movements into import prices is incomplete in the short and medium term. Thus import prices ( $P_t^M$ ) are given by the CES aggregate of bilateral export price ( $P_t^{X,f}$ ) charged by the respective trading partners:

$$P_t^M = s f p m P_{t-1}^M + (1 - s f p m) \left( \sum_f s^f \left( \frac{e_t P_t^{X,f}}{e_t^f} \right)^{1 - \sigma_1} \right)^{\frac{1}{1 - \sigma_1}} \quad 7.47$$

where  $e_t$  is the nominal exchange rate w.r.t. the rest of the world currency and  $s f p m$  is a lag parameter.

Total exports of the domestic economy are the sum of all foreign regions' imports stemming from the domestic region, which corresponds to the exports of the domestic region to all other regions:

$$X_t = \sum_f X_t^f \quad 7.48$$

Aggregate export prices are a weighted average over bilateral import prices in export destinations,  $P_t^{M*,f}$ , and the bilateral exchange rate:

$$P_t^X = \left( \sum_f \frac{P_t^{M*,f}}{e_t^f} X_t^f \right) / X_t \quad 7.49$$

The terms of trade of the economy are defines as the ratio of export over import prices:

$$TOT_t \equiv P_t^X / P_t^M \quad 7.50$$

The trade balance of the domestic economy is net trade in value terms:

$$TB_t \equiv \sum_f \frac{P_t^{M^*,f}}{e_t^f} X_t^f - \sum_f P_t^{M,f} M_t^f \quad 7.51$$

Adding interest income on net foreign assets (NFA) to the trade balance gives the current account position of the domestic economy:

$$\frac{CA_t}{P_t} \equiv r_{t-1}^F rert B_{t-1}^F + \frac{TB_t}{P_t} - CO_t^{EU} + GR_t^{EU} \quad 7.52$$

where  $r_t^F$  denotes real interest paid on net foreign asset denominated in the reserve currency of the world economy, which in the model is the U.S. dollar.

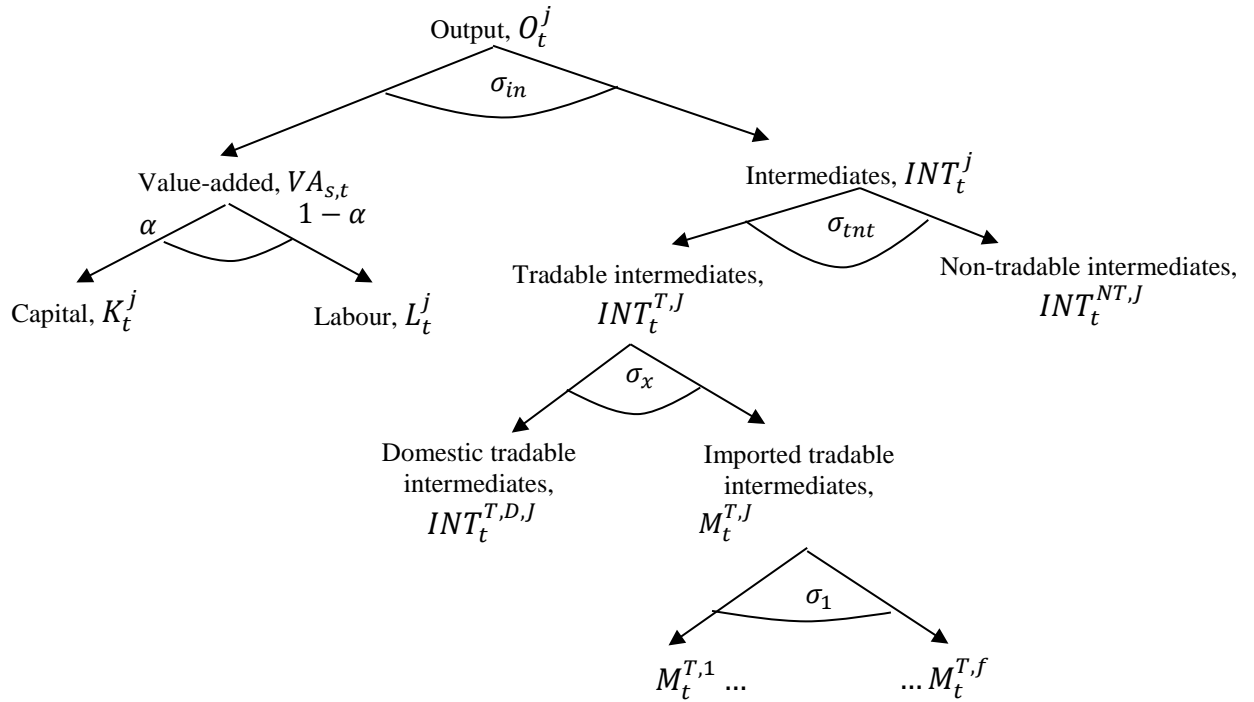
The law of motion for the NFA position is:

$$rert B_t^F = (1 + r_{t-1}^F) rert B_{t-1}^F + \frac{TB_t}{P_t} - CO_t^{EU} + GR_t^{EU} \quad 7.53$$

The focus on the NFA position abstracts from valuation effects on gross foreign assets or liabilities that otherwise could affect the financial wealth of domestic households.

Finally, Figure 7.1 below shows the nested structure for production with the corresponding elasticities for a stylised review of our model structure:

Figure 7.1. The production nesting scheme



## 8. APPENDIX C: CALIBRATION

We calibrate our model in a multi-country setting for all 27 Member States and the rest of the world. Country-specific macroeconomic variables that characterise the steady state of the model are calibrated on the basis of national accounts, fiscal and trade data. We use Eurostat data for the breakdown of government spending into consumption, investment and transfers, and we use effective tax rates on labour, capital and consumption to determine government revenues. The baseline government consumption and debt-to-GDP ratios reflect their average ratios observed over the last 5 years. As for government investments, we use the average over the last 20 years because public investments financed from the EU Cohesion Funds can distort current public investment spending data over several years during their programming period.

The monetary policy parameters in standard times ( $\rho_i^{NoZLB}$ ) are adopted from Ratto et al. (2009). To account for accommodative monetary policy at the ZLB, we set  $\rho_i^{ZLB} = 0.94$ . Behavioural parameters that govern the dynamic adjustment to shocks are based on earlier estimates of version of the QUEST model (see Burgert et. al. 2020 for detailed list of parameter calibration). Table 8.1 summarises the common parameter values that are used across all regions.

Table 8.1. Model parameters – common values across all regions

Parameter	Value	Description
$\beta$	0.997	Discount factor Ricardian households
$h^c$	0.85	Habit persistence in consumption
$1/\kappa$	0.2	Labour supply elasticity
$\gamma_L$	25	Head-count adjustment costs parameter
$\gamma_P$	20	Price adjustment costs parameter
$\gamma_{u,1}$	0.04(T); 0.03(NT)	Linear capacity-utilisation adjustment cost
$\gamma_{u,2}$	0.05	Quadratic capacity-utilisation adjustment cost
$\gamma_K$	20	Capital adjustment cost
$\gamma_I$	75	Investment adjustment cost
$\gamma^w$	120	Wage adjustment cost
$sfp$	0.9	Share of forward looking T price setters
$sfp_m$	0.5	Share of forward looking import price setters
$sfw$	0.9	Share of forward looking wage setters
$sfp_h$	1	Share of forward looking NT price setters
$wrlag$	0.9	Real wage inertia
$\sigma_{tnt}$	0.5	Elasticity of substitution T-NT
$\sigma_x$	1.2	Elasticity of substitution in total trade
$\sigma_1$	0.99	Elasticity of substitution between import sources
$\alpha$	0.65	Cobb-Douglas labour parameter
$\alpha_g$	0.12	Cobb-Douglas public capital stock parameter
$\sigma_{in}$	0.5	Elasticity of substitution between value added and intermediates
$\theta$	6	Elasticity of substitution between types of labour
$\delta^{K,T}$	0.015	Depreciation rate T capital stock
$\delta^{K,NT}$	0.005	Depreciation rate NT capital stock
$\delta^g$	0.013	Depreciation rate public capital stock
$\tau^b$	0.01	Tax rule parameter on debt
$\tau^{def}$	0.1	Tax rule parameter on deficit
$\rho_i^{N^oZLB}$	0.82	Interest rate smoothing in Taylor rule (standard times)
$\rho_i^{ZLB}$	0.94	Interest rate smoothing in Taylor rule (ZLB regime)
$\tau_\pi$	1.5	Reaction to inflation in Taylor rule

Trade openness in terms of aggregate import shares matches data from the Eurostat national accounts statistics. The bilateral import shares are compiled from export and import data of goods in the IMF Direction of Trade statistics and from EUROSTAT, OECD and WTO statistical sources on the trade in services. All import shares are expressed in their 2018 values. We show the full trade matrix in Graph 8.1. in % of the importing partner's GDP The steady-state shares of domestic demand for tradables and non-tradables and the share of intermediates in tradable and non-tradable sector production are based on input-output tables from the WIOD database (Timmers et al., 2015). We classify individual sectors as traded if their average ratio of exports to output is above 10% at the EU level. The elasticity of substitution between tradables and non-tradables  $\sigma_{tnt}$  is set to 0.5 in line with the IMF's GIMF model (Kumhof et al.2010). The elasticity of substitution between bundles of domestic and foreign goods ( $\sigma_x$ ) is set to 1.2 based on Ratto et al. (2008). The elasticity of substitution between imports of different origins ( $\sigma_1$ ) is set to 0.99 which is in the range of parameter values applied in the IMF's multi-region macromodels (Kumhof et al. 2010, Elekdag and Muir, 2014).



Table 8.2. The trade matrix used in the model calibration (exports)

BE	0.00	0.20	0.80	0.85	16.01	0.08	2.04	0.45	2.75	14.73	0.10	4.72	0.09	0.07	0.16	2.80	0.63	0.03	10.75	1.06	1.99	0.62	0.54	0.14	0.29	0.57	1.80
BG	1.98	0.00	1.61	0.52	9.88	0.08	0.36	4.39	1.61	2.59	0.26	4.53	0.28	0.07	0.14	0.07	1.03	0.05	1.62	1.77	1.53	0.28	4.88	0.42	0.65	0.22	0.66
CZ	1.91	0.45	0.00	0.91	27.38	0.14	0.80	0.25	2.64	4.53	0.27	3.48	0.06	0.11	0.29	0.21	2.53	0.02	2.79	3.83	5.14	0.30	1.27	0.37	6.98	0.52	1.39
DK	0.79	0.07	0.35	0.00	6.83	0.12	0.54	0.22	0.96	1.69	0.05	1.17	0.03	0.11	0.16	0.15	0.24	0.05	1.93	0.31	1.30	0.16	0.16	0.05	0.12	1.06	5.58
DE	1.41	0.13	1.31	0.74	0.00	0.05	0.48	0.22	1.53	3.74	0.10	2.23	0.03	0.05	0.10	0.53	0.80	0.03	2.53	2.29	2.04	0.33	0.55	0.15	0.47	0.40	0.91
EE	1.15	0.17	0.40	2.38	5.14	0.00	0.42	0.13	0.98	1.81	0.03	0.88	0.19	5.48	3.80	0.14	0.19	0.12	1.82	0.55	2.12	0.17	0.27	0.09	0.17	14.37	8.13
IE	5.08	0.08	0.56	0.97	9.27	0.03	0.00	0.40	2.06	5.78	0.04	3.95	0.05	0.05	0.05	1.46	0.44	0.06	4.90	0.65	1.03	0.39	0.24	0.06	0.09	0.58	1.69
EL	0.55	1.00	0.23	0.36	3.54	0.04	0.27	0.00	0.89	1.63	0.07	2.80	1.41	0.03	0.04	0.11	0.14	0.13	0.82	0.47	0.54	0.14	0.78	0.23	0.10	0.21	0.35
ES	0.90	0.12	0.23	0.33	3.96	0.03	0.60	0.22	0.00	4.85	0.04	2.30	0.04	0.03	0.07	0.23	0.16	0.03	1.27	0.31	0.59	2.04	0.28	0.05	0.11	0.16	0.44
FR	1.99	0.05	0.22	0.21	3.92	0.02	0.64	0.13	2.12	0.00	0.03	2.05	0.02	0.02	0.03	0.50	0.17	0.02	1.14	0.21	0.49	0.37	0.21	0.05	0.15	0.14	0.36
HR	0.79	0.21	0.81	0.34	8.51	0.03	0.39	0.24	0.76	1.42	0.00	5.36	0.02	0.03	0.07	0.05	1.94	0.27	0.97	4.10	1.15	0.14	0.56	4.14	0.69	0.23	0.67
IT	0.83	0.15	0.36	0.23	3.96	0.03	0.43	0.30	1.47	3.22	0.18	0.00	0.06	0.03	0.07	0.30	0.26	0.06	0.77	0.76	0.78	0.24	0.47	0.23	0.19	0.13	0.36
CY	0.53	0.50	0.40	1.18	6.37	0.31	0.45	4.60	0.45	0.77	0.04	1.20	0.00	0.15	0.14	0.68	0.45	0.89	2.22	0.82	1.45	0.11	0.64	0.12	0.30	0.32	0.99
LV	0.70	0.17	0.55	2.49	4.46	5.52	0.59	0.12	0.78	1.63	0.04	1.08	0.28	0.00	7.37	0.09	0.23	0.05	1.51	0.54	1.94	0.09	0.13	0.09	0.22	1.53	4.94
LT	1.26	0.20	0.71	2.26	6.45	3.19	0.37	0.11	2.24	2.30	0.08	1.86	0.06	5.66	0.00	0.14	0.40	0.02	2.29	1.01	5.08	0.17	0.26	0.10	0.21	1.29	3.46
LU	15.03	0.16	1.02	1.21	33.16	0.14	5.10	0.44	6.47	25.81	0.05	20.76	0.22	0.08	0.08	0.00	0.89	0.21	8.70	2.00	1.95	0.94	0.63	0.23	0.55	0.99	4.19
HU	2.02	0.95	3.21	1.06	24.33	0.06	0.56	0.44	2.53	3.67	1.48	4.43	0.06	0.14	0.18	0.26	0.00	0.02	2.76	5.14	3.67	0.45	4.87	0.79	4.64	0.47	1.50
MT	0.85	0.59	0.59	2.05	14.99	0.24	2.24	2.21	2.87	6.33	0.14	5.56	1.23	0.07	0.15	0.98	0.28	0.00	5.14	1.27	1.82	0.73	0.57	0.07	0.15	0.51	3.59
NL	8.83	0.18	1.27	1.38	22.10	0.10	6.64	0.45	2.93	7.66	0.12	3.67	0.08	0.08	0.19	0.60	0.77	0.07	0.00	1.18	2.12	0.62	0.52	0.13	0.28	0.92	2.28
AT	0.88	0.28	1.70	0.34	18.54	0.05	0.41	0.20	0.78	2.05	0.39	3.30	0.04	0.05	0.08	0.22	1.89	0.06	1.30	0.00	1.62	0.13	0.95	0.88	2.04	0.30	0.71
PL	1.23	0.24	2.81	1.06	15.13	0.22	0.53	0.20	1.38	3.17	0.17	2.37	0.05	0.28	0.71	0.31	1.24	0.01	2.37	1.26	0.00	0.23	1.02	0.17	1.38	0.56	1.71
PT	1.01	0.07	0.20	0.36	4.92	0.02	0.80	0.13	8.64	5.77	0.02	1.63	0.11	0.02	0.04	0.33	0.14	0.03	1.51	0.38	0.49	0.00	0.26	0.06	0.21	0.27	0.44
RO	1.03	1.24	0.98	0.29	9.07	0.03	0.28	0.49	1.49	3.18	0.12	4.84	0.11	0.03	0.05	0.17	1.67	0.01	1.63	1.66	1.21	0.14	0.00	0.22	0.86	0.13	0.37
SI	1.08	0.65	2.16	0.82	17.18	0.11	0.29	0.41	1.55	4.29	6.10	11.04	0.13	0.08	0.24	0.45	3.72	0.03	1.54	8.81	3.70	0.25	1.59	0.00	2.34	0.26	0.90
SK	1.29	0.55	9.98	0.66	20.74	0.11	0.28	0.31	2.17	5.69	0.49	4.15	0.08	0.15	0.20	0.22	5.68	0.01	1.86	5.85	6.92	0.28	2.16	0.63	0.00	0.30	1.21
FI	0.98	0.03	0.18	0.71	4.67	0.92	0.55	0.08	0.66	1.13	0.02	1.11	0.05	0.26	0.29	0.07	0.12	0.01	1.58	0.49	0.82	0.10	0.08	0.03	0.08	0.00	4.45
SE	1.31	0.05	0.29	3.39	4.19	0.34	0.56	0.10	0.81	1.87	0.03	1.08	0.02	0.12	0.23	0.36	0.17	0.05	1.75	0.63	1.20	0.17	0.13	0.04	0.13	3.14	0.00
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	

Note: This graph displays export shares in % of GDP across countries. For example, the cell in row BG and column BE indicates that Bulgarian exports to Belgium are 1.98% of Bulgarian GDP. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Table 8.3. The trade matrix used in the model calibration (imports)

BE	0.00	1.61	1.75	1.29	2.20	1.49	2.88	1.16	1.05	2.87	0.85	1.23	1.88	1.06	1.66	21.44	2.13	0.96	6.39	1.27	1.84	1.39	1.21	1.41	1.49	1.13	1.76
BG	0.24	0.00	0.43	0.10	0.17	0.18	0.06	1.37	0.08	0.06	0.28	0.14	0.73	0.13	0.17	0.07	0.43	0.20	0.12	0.26	0.17	0.08	1.34	0.51	0.41	0.05	0.08
CZ	0.88	1.68	0.00	0.64	1.72	1.17	0.52	0.30	0.46	0.40	1.09	0.41	0.62	0.82	1.32	0.75	3.92	0.28	0.76	2.10	2.18	0.31	1.31	1.69	16.47	0.47	0.62
DK	0.52	0.36	0.51	0.00	0.61	1.34	0.50	0.37	0.24	0.22	0.27	0.20	0.48	1.16	1.07	0.77	0.54	1.11	0.76	0.24	0.79	0.23	0.23	0.30	0.42	1.37	3.58
DE	10.31	7.54	20.83	8.18	0.00	6.80	4.95	4.02	4.25	5.32	6.75	4.23	4.73	5.62	7.34	29.90	19.65	7.20	10.98	19.91	13.74	5.35	9.10	10.75	17.81	5.70	6.49
EE	0.06	0.08	0.05	0.20	0.04	0.00	0.03	0.02	0.02	0.02	0.01	0.01	0.23	4.88	2.16	0.06	0.04	0.25	0.06	0.04	0.11	0.02	0.03	0.05	0.05	1.59	0.45
IE	3.61	0.49	0.86	1.05	0.90	0.43	0.00	0.73	0.56	0.80	0.26	0.73	0.81	0.57	0.34	7.94	1.05	1.49	2.07	0.55	0.67	0.62	0.38	0.45	0.34	0.81	1.18
EL	0.21	3.22	0.20	0.21	0.19	0.28	0.15	0.00	0.13	0.12	0.26	0.28	11.85	0.15	0.15	0.34	0.19	1.87	0.19	0.22	0.20	0.12	0.69	0.91	0.20	0.16	0.14
ES	2.36	2.48	1.34	1.33	1.42	1.24	2.19	1.50	0.00	2.48	1.02	1.56	2.05	1.15	1.98	4.59	1.44	2.64	1.97	0.96	1.43	12.00	1.62	1.30	1.47	0.85	1.12
FR	10.18	1.93	2.45	1.62	2.76	1.62	4.64	1.69	4.16	0.00	1.16	2.73	1.66	1.26	1.75	19.56	2.94	3.87	3.47	1.31	2.33	4.21	2.45	2.60	4.02	1.43	1.82
HR	0.09	0.19	0.20	0.06	0.13	0.06	0.06	0.07	0.03	0.03	0.00	0.16	0.05	0.05	0.08	0.05	0.74	1.11	0.07	0.55	0.12	0.03	0.14	4.69	0.40	0.05	0.07
IT	3.18	4.58	3.04	1.34	2.09	1.72	2.32	2.95	2.16	2.42	6.20	0.00	4.71	1.96	2.63	8.73	3.39	8.63	1.77	3.49	2.77	2.09	4.05	9.06	3.74	0.96	1.34
CY	0.02	0.19	0.04	0.08	0.04	0.26	0.03	0.55	0.01	0.01	0.02	0.01	0.00	0.11	0.07	0.24	0.07	1.52	0.06	0.05	0.06	0.01	0.07	0.06	0.07	0.03	0.04
LV	0.04	0.09	0.08	0.24	0.04	6.21	0.05	0.02	0.02	0.02	0.02	0.02	0.38	0.00	4.72	0.04	0.05	0.11	0.06	0.04	0.11	0.01	0.02	0.06	0.07	0.19	0.31
LT	0.12	0.16	0.15	0.34	0.09	5.60	0.05	0.03	0.08	0.04	0.07	0.05	0.13	8.83	0.00	0.11	0.13	0.06	0.13	0.12	0.46	0.04	0.06	0.10	0.11	0.25	0.33
LU	1.96	0.17	0.29	0.24	0.59	0.32	0.94	0.15	0.32	0.66	0.06	0.70	0.62	0.17	0.11	0.00	0.39	0.99	0.67	0.31	0.24	0.28	0.19	0.30	0.37	0.25	0.53
HU	0.60	2.31	2.07	0.48	0.99	0.33	0.23	0.33	0.29	0.21	3.87	0.34	0.37	0.64	0.52	0.59	0.00	0.17	0.49	1.81	1.00	0.30	3.24	2.35	7.06	0.27	0.43
MT	0.02	0.13	0.04	0.09	0.06	0.12	0.09	0.15	0.03	0.03	0.04	0.04	0.72	0.03	0.04	0.20	0.03	0.00	0.08	0.04	0.05	0.04	0.04	0.02	0.02	0.03	0.10
NL	14.84	2.44	4.66	3.52	5.10	3.06	15.72	1.94	1.88	2.51	1.72	1.60	2.94	2.17	3.23	7.69	4.40	4.02	0.00	2.36	3.29	2.32	1.95	2.22	2.46	3.06	3.74
AT	0.74	1.89	3.11	0.43	2.13	0.69	0.48	0.43	0.25	0.34	2.86	0.72	0.80	0.64	0.67	1.38	5.36	1.88	0.65	0.00	1.25	0.25	1.79	7.35	8.80	0.49	0.58
PL	1.33	2.14	6.63	1.75	2.25	4.27	0.80	0.56	0.57	0.67	1.62	0.67	1.17	4.70	7.78	2.58	4.55	0.45	1.52	1.63	0.00	0.55	2.49	1.82	7.68	1.19	1.81
PT	0.45	0.26	0.19	0.25	0.30	0.17	0.50	0.14	1.47	0.50	0.09	0.19	1.10	0.17	0.18	1.13	0.21	0.44	0.40	0.20	0.20	0.00	0.26	0.27	0.48	0.24	0.19
RO	0.46	4.52	0.95	0.20	0.55	0.25	0.18	0.56	0.25	0.28	0.47	0.56	1.07	0.23	0.23	0.59	2.52	0.23	0.43	0.88	0.50	0.14	0.00	1.00	1.96	0.11	0.16
SI	0.11	0.53	0.47	0.12	0.23	0.20	0.04	0.11	0.06	0.08	5.39	0.29	0.27	0.12	0.24	0.34	1.26	0.12	0.09	1.05	0.34	0.05	0.36	0.00	1.20	0.05	0.09
SK	0.25	0.88	4.23	0.20	0.55	0.38	0.08	0.16	0.16	0.22	0.84	0.21	0.35	0.46	0.38	0.33	3.73	0.05	0.22	1.36	1.24	0.12	0.94	1.22	0.00	0.11	0.23
FI	0.50	0.13	0.20	0.55	0.32	8.27	0.40	0.10	0.13	0.11	0.08	0.15	0.52	2.12	1.47	0.29	0.20	0.19	0.48	0.29	0.39	0.11	0.09	0.15	0.21	0.00	2.21
SE	1.34	0.38	0.64	5.27	0.59	6.21	0.80	0.27	0.32	0.37	0.27	0.29	0.34	1.95	2.41	2.83	0.61	1.93	1.06	0.78	1.14	0.39	0.29	0.42	0.68	6.33	0.00

Note: This table displays import shares in % of GDP across countries. For example, the cell in row BG and column BE indicates that Belgian imports from Bulgaria are 0.24% of Belgian GDP. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

## 9. APPENDIX D: SOLUTION ALGORITHM

We solve the nonlinear model by a Newton-Raphson solution algorithm as developed by Laffarque (1990), Boucekkine (1995) and Juillard (1996), and implemented in the TROLL software. Let  $y_t$  ( $n \times 1$ ) and  $x_t$  ( $k \times 1$ ) be vectors of endogenous and exogenous variables respectively. The model can be written compactly as:

$$f_t(y_{t-1}, y_t, E_t y_{t+1}, x_t) = 0$$

where  $f_t$  is a vector of  $n$  nonlinear dynamic equations. The presence of predetermined state variables  $y_{t-1}$  and forward-looking expectations (jump variables)  $E_t y_{t+1}$  introduces simultaneity across time periods. A way of solving the model (with starting date  $t$ ) is to stack the system for the  $T+1$  periods:

$$F(z, x; t) = \begin{bmatrix} f_t(z_t, x_t) \\ \vdots \\ f_{t+j}(z_{t+j}, x_{t+j}) \\ \vdots \\ f_{t+T}(z_{t+T}, x_{t+T}) \end{bmatrix} = 0$$

where  $z_{t+j} = (y_{t+j-1}, y_{t+j}, E_t y_{t+j+1})$ . This stacked system of equations is then solved with the Newton-Raphson method subject to the predetermined variables  $y_{t-1}$  and the terminal conditions  $y_{t+T+1}$ .

Boucekkine, R. (1995). An Alternative Methodology for Solving Nonlinear Forward-Looking Models. *Journal of Economic Dynamics and Control* 19: 711-734.

Juillard, M. (1996). DYNARE: A Program for the Resolution and Simulation of Dynamic Models with Forward Variables Through the Use of a Relaxation Algorithm. CEPREMAP Working Paper, No. 9602.

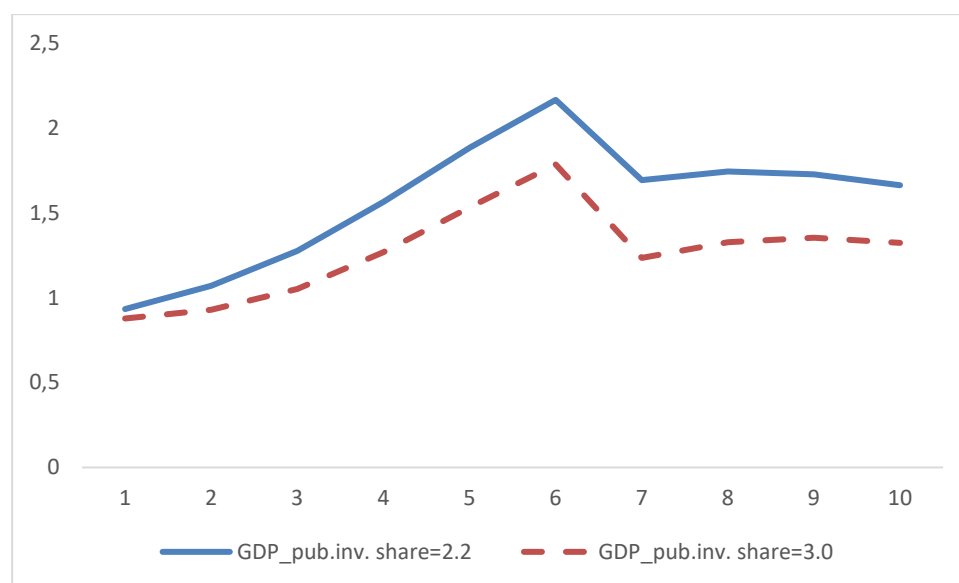
Laffarque, J. (1990). Résolution d'un Modèle Macroéconomique avec Anticipations Rationnelles. *Annales d'Economie et Statistique* 17: 97-119.

## 10. APPENDIX E: The role of initial public capital

This Appendix illustrates situations in which the economy starts from a lower initial level of public capital. To isolate this aspect as much as possible, the simulations consider different model versions for Germany. In the first model version, the calibrated initial level of public capital depends on the steady-state output shares of public investment. In line with AMECO data for Germany, this share is set to 2.2% (average over 2000-2020). By contrast, the second “counterfactual” model version uses an “artificial” calibration in which the public investment share is higher than the empirical average (3.0% instead of 2.2%). All other parameters remain the same. Since the initial level of public capital is higher in this “artificial” version, it serves as a testbed to investigate the importance of the initial amount of public capital for the size of fiscal multipliers.

Long-run multipliers are higher if the economy is starting with a low level of public capital, as shown in Graph D.1. The lower the initial public capital stock is, the higher are the gains from one more unit of public investment. In the case of a lower initial public capital, the peak output effects 20-30% larger. This finding suggests that public investment is likely more effective in economies with declining public investment trends and backlogs in infrastructure maintenance.

Graph 10.1. Illustrative simulations results under different assumptions on the initial public capital level



Note: This graph reports the level of German real GDP in per cent deviation from a no-policy change baseline. Model simulations use a model of DE, the rest-of-the-EU, and the rest-of-the-world and use different calibration of the initial level of public capital (implying public investment shares of 2.2% for the empirical model and 3.0% for the “artificial” variant). The horizontal axis is in years.

# 11. APPENDIX F: Detailed simulations for all MS

Table 11.1. GDP effects NGEU by MS (six-year profile)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2040
BE_baseline	0.5	0.7	0.8	0.8	0.9	0.9	0.7	0.6	0.5	0.4	0.2
BE_of_which_spillover	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0
BE_low_productivity	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.1
BG_baseline	1.5	2.5	2.5	2.6	2.8	3	2.2	1.4	1.6	1.7	1.1
BG_of_which_spillover	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.1
BG_low_productivity	1.2	2.1	1.9	1.8	1.9	1.9	1.1	0.3	0.4	0.5	0.5
CZ_baseline	0.3	0.9	1	1.1	1.1	1.2	0.9	0.6	0.6	0.6	0.3
CZ_of_which_spillover	-0.3	0	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1
CZ_low_productivity	0.2	0.6	0.7	0.7	0.7	0.8	0.5	0.2	0.2	0.2	0.1
DK_baseline	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.1
DK_of_which_spillover	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0
DK_low_productivity	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0
DE_baseline	0.4	0.6	0.6	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.2
DE_of_which_spillover	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0
DE_low_productivity	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.1
EE_baseline	0.9	1.3	1.2	1.3	1.3	1.3	1	0.6	0.6	0.6	0.3
EE_of_which_spillover	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0
EE_low_productivity	0.6	0.9	0.8	0.8	0.8	0.9	0.5	0.2	0.2	0.2	0.1
IE_baseline	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0
IE_of_which_spillover	0.6	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0.1	0
IE_low_productivity	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0
EL_baseline	1.6	2.7	2.7	2.8	3	3.3	2.3	1.5	1.7	1.8	1.2
EL_of_which_spillover	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0
EL_low_productivity	1.4	2.3	2.1	2	2.1	2.1	1.1	0.2	0.4	0.6	0.5
ES_baseline	1	1.6	1.7	1.8	1.9	2.1	1.7	1.2	1.3	1.3	0.8
ES_of_which_spillover	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0
ES_low_productivity	0.8	1.3	1.2	1.2	1.2	1.3	0.8	0.4	0.5	0.5	0.3
FR_baseline	0.5	0.7	0.7	0.7	0.7	0.8	0.6	0.5	0.5	0.4	0.2
FR_of_which_spillover	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0
FR_low_productivity	0.3	0.4	0.4	0.4	0.4	0.5	0.3	0.2	0.2	0.2	0.1
HR_baseline	1.5	2.6	2.5	2.6	2.7	2.9	2.1	1.3	1.5	1.6	1.1
HR_of_which_spillover	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.1
HR_low_productivity	1.3	2.2	1.9	1.8	1.8	1.9	1	0.2	0.4	0.5	0.5
IT_baseline	1	1.8	1.9	2	2.3	2.5	2.1	1.6	1.7	1.8	1.1
IT_of_which_spillover	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0
IT_low_productivity	0.8	1.4	1.3	1.3	1.4	1.5	1	0.5	0.6	0.6	0.5
CY_baseline	1	1.5	1.5	1.6	1.7	1.8	1.4	1.1	1.1	1.1	0.6
CY_of_which_spillover	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.1

CY_low_productivity	0.7	1	1	1	1	1.1	0.7	0.3	0.4	0.4	0.2
LV_baseline	1.1	1.8	1.7	1.8	1.9	2	1.5	1	1.1	1.1	0.7
LV_of_which_spillover	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0
LV_low_productivity	0.8	1.4	1.3	1.2	1.3	1.3	0.8	0.2	0.3	0.4	0.3
LT_baseline	0.9	1.4	1.3	1.4	1.5	1.6	1.2	0.9	0.9	0.9	0.5
LT_of_which_spillover	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0
LT_low_productivity	0.6	1	0.9	0.9	0.9	1	0.6	0.2	0.3	0.3	0.2
LU_baseline	0.7	0.8	0.9	0.9	0.8	0.8	0.6	0.4	0.2	0.1	0.1
LU_of_which_spillover	0.7	0.8	0.8	0.8	0.8	0.7	0.6	0.3	0.2	0.1	0
LU_low_productivity	0.3	0.4	0.5	0.5	0.5	0.5	0.4	0.2	0.1	0.1	0
HU_baseline	0.5	1.2	1.3	1.4	1.5	1.6	1.2	0.8	0.8	0.7	0.5
HU_of_which_spillover	-0.4	0	0.2	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.1
HU_low_productivity	0.3	0.9	0.9	0.9	1	1	0.6	0.2	0.3	0.3	0.2
MT_baseline	0.9	1.1	1	1	1.1	1.1	0.8	0.5	0.5	0.4	0.2
MT_of_which_spillover	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0.1	0
MT_low_productivity	0.5	0.7	0.7	0.7	0.7	0.7	0.4	0.2	0.1	0.1	0.1
NL_baseline	0.4	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.1
NL_of_which_spillover	0.3	0.4	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0
NL_low_productivity	0.2	0.3	0.3	0.3	0.4	0.4	0.3	0.2	0.2	0.1	0
AT_baseline	0.5	0.6	0.7	0.7	0.7	0.7	0.6	0.5	0.4	0.4	0.2
AT_of_which_spillover	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.1
AT_low_productivity	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.2	0.2	0.2	0.1
PL_baseline	0.7	1.3	1.5	1.6	1.7	1.8	1.4	0.9	1	0.9	0.6
PL_of_which_spillover	-0.4	-0.2	0	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1
PL_low_productivity	0.4	0.9	1	1	1.1	1.1	0.7	0.3	0.3	0.3	0.2
PT_baseline	1.1	1.9	1.9	2	2.2	2.4	1.9	1.4	1.5	1.5	0.9
PT_of_which_spillover	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.1
PT_low_productivity	0.9	1.4	1.3	1.3	1.4	1.5	0.9	0.4	0.5	0.6	0.4
RO_baseline	1.2	2.2	2.3	2.5	2.7	2.9	2.2	1.5	1.6	1.6	1
RO_of_which_spillover	-0.6	-0.3	0	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1
RO_low_productivity	0.7	1.5	1.5	1.6	1.7	1.8	1.1	0.4	0.5	0.5	0.4
SI_baseline	0.9	1.4	1.4	1.5	1.6	1.6	1.3	0.9	0.9	0.8	0.5
SI_of_which_spillover	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.3	0.2	0.1
SI_low_productivity	0.6	1	1	1	1	1.1	0.7	0.3	0.3	0.3	0.2
SK_baseline	1.2	1.8	1.8	1.9	2	2.1	1.6	1.1	1.1	1.1	0.6
SK_of_which_spillover	0.5	0.6	0.6	0.6	0.7	0.6	0.6	0.4	0.3	0.2	0.1
SK_low_productivity	0.9	1.4	1.3	1.3	1.3	1.3	0.8	0.3	0.3	0.4	0.3
FI_baseline	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.3	0.1
FI_of_which_spillover	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	0
FI_low_productivity	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0
SE_baseline	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1
SE_of_which_spillover	-0.1	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SE_low_productivity	0	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0

EU_baseline	0.6	1.0	1.0	1.1	1.2	1.2	1.0	0.8	0.8	0.7	0.4
EU_of_which_spillover	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1
EU_low_productivity	0.4	0.6	0.6	0.7	0.7	0.7	0.5	0.3	0.3	0.3	0.2

Note: This table reports the level of real GDP in per cent deviation from a no-policy change baseline. For each MS, the first line (“\_baseline”) reports the GDP effects for the baseline model including spillover, the second line (“\_of\_which\_spillover”) reports the contribution of NGEU spillover, while the last line (“\_low\_productivity”) displays results from a low productivity scenario including spillover. Note that, in the low productivity scenario, the smaller growth effects in each MS also reduce the spillover. These results are based on stylised assumptions regarding the nature of the investment and its time profile. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Table 11.2. GDP effects NGEU by MS (fast profile)

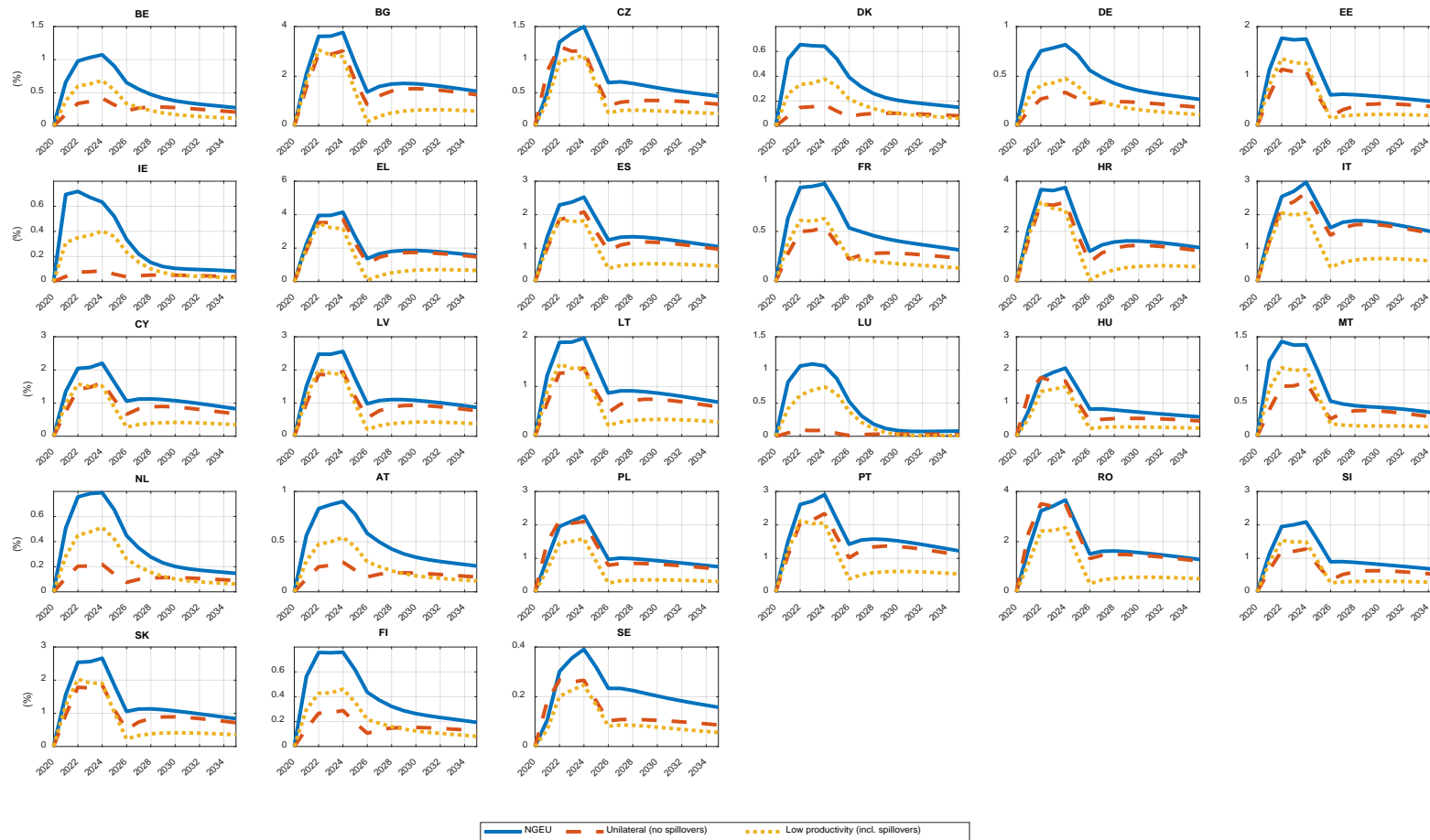
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2040
BE_baseline	0.7	1	1	1.1	0.9	0.7	0.6	0.5	0.4	0.4	0.2
BE_of_which_spillover	0.5	0.6	0.7	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0
BE_low_productivity	0.4	0.6	0.6	0.7	0.5	0.3	0.3	0.2	0.2	0.2	0.1
BG_baseline	2.1	3.6	3.6	3.8	2.5	1.4	1.6	1.7	1.7	1.7	1
BG_of_which_spillover	0.5	0.7	0.7	0.7	0.7	0.5	0.4	0.3	0.2	0.2	0.1
BG_low_productivity	1.8	3.1	2.8	2.8	1.4	0.2	0.4	0.5	0.6	0.6	0.4
CZ_baseline	0.5	1.3	1.4	1.5	1.1	0.7	0.7	0.6	0.6	0.6	0.3
CZ_of_which_spillover	-0.3	0.1	0.3	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.1
CZ_low_productivity	0.4	1	1	1.1	0.6	0.2	0.2	0.2	0.2	0.2	0.1
DK_baseline	0.5	0.7	0.6	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.1
DK_of_which_spillover	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0
DK_low_productivity	0.3	0.3	0.3	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0
DE_baseline	0.5	0.8	0.8	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.2
DE_of_which_spillover	0.4	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0
DE_low_productivity	0.3	0.4	0.4	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.1
EE_baseline	1.1	1.8	1.7	1.7	1.2	0.6	0.6	0.6	0.6	0.6	0.3
EE_of_which_spillover	0.5	0.6	0.6	0.6	0.6	0.4	0.3	0.2	0.2	0.1	0.1
EE_low_productivity	0.8	1.4	1.3	1.3	0.7	0.2	0.2	0.2	0.2	0.2	0.1
IE_baseline	0.7	0.7	0.7	0.6	0.5	0.3	0.2	0.2	0.1	0.1	0
IE_of_which_spillover	0.7	0.6	0.6	0.5	0.5	0.3	0.2	0.1	0.1	0.1	0
IE_low_productivity	0.3	0.4	0.4	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0
EL_baseline	2.3	4	4	4.1	2.7	1.4	1.7	1.8	1.9	1.9	1.1
EL_of_which_spillover	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0
EL_low_productivity	2	3.5	3.2	3.2	1.5	0.1	0.4	0.5	0.6	0.7	0.5
ES_baseline	1.3	2.3	2.4	2.5	1.9	1.2	1.3	1.3	1.3	1.3	0.8
ES_of_which_spillover	0.3	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0
ES_low_productivity	1.1	1.9	1.8	1.8	1.1	0.4	0.5	0.5	0.5	0.5	0.3
FR_baseline	0.6	0.9	0.9	1	0.8	0.5	0.5	0.5	0.4	0.4	0.2
FR_of_which_spillover	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0
FR_low_productivity	0.4	0.6	0.6	0.6	0.4	0.2	0.2	0.2	0.2	0.2	0.1
HR_baseline	2.1	3.7	3.6	3.7	2.4	1.2	1.5	1.6	1.6	1.6	1
HR_of_which_spillover	0.4	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.1
HR_low_productivity	1.8	3.2	2.9	2.8	1.3	0.1	0.3	0.5	0.6	0.6	0.4
IT_baseline	1.4	2.5	2.7	3	2.3	1.6	1.8	1.8	1.8	1.8	1.1
IT_of_which_spillover	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0
IT_low_productivity	1.2	2.1	2	2	1.2	0.4	0.6	0.6	0.7	0.7	0.4
CY_baseline	1.3	2	2.1	2.2	1.6	1.1	1.1	1.1	1.1	1.1	0.6
CY_of_which_spillover	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.1
CY_low_productivity	1	1.6	1.5	1.5	0.9	0.3	0.4	0.4	0.4	0.4	0.2
LV_baseline	1.5	2.5	2.5	2.6	1.7	1	1.1	1.1	1.1	1.1	0.6
LV_of_which_spillover	0.5	0.6	0.6	0.6	0.6	0.4	0.3	0.2	0.2	0.1	0.1



LV_low_productivity	1.2	2	1.9	1.9	1	0.2	0.3	0.4	0.4	0.4	0.3
LT_baseline	1.2	1.9	1.9	2	1.4	0.9	0.9	0.9	0.9	0.9	0.5
LT_of_which_spillover	0.5	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1
LT_low_productivity	0.9	1.4	1.4	1.4	0.8	0.2	0.3	0.3	0.3	0.3	0.2
LU_baseline	0.8	1.1	1.1	1.1	0.9	0.5	0.3	0.2	0.1	0.1	0.1
LU_of_which_spillover	0.8	1	1	1	0.8	0.5	0.3	0.2	0.1	0.1	0
LU_low_productivity	0.4	0.6	0.7	0.7	0.6	0.4	0.2	0.1	0.1	0	0
HU_baseline	0.8	1.8	1.9	2.1	1.5	0.8	0.8	0.8	0.8	0.7	0.4
HU_of_which_spillover	-0.5	0	0.3	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.1
HU_low_productivity	0.5	1.4	1.4	1.5	0.9	0.2	0.3	0.3	0.3	0.3	0.2
MT_baseline	1.1	1.4	1.4	1.4	1	0.5	0.5	0.5	0.4	0.4	0.2
MT_of_which_spillover	0.7	0.7	0.6	0.6	0.5	0.3	0.1	0.1	0.1	0.1	0
MT_low_productivity	0.7	1	1	1	0.6	0.2	0.2	0.2	0.2	0.2	0.1
NL_baseline	0.5	0.8	0.8	0.8	0.7	0.4	0.3	0.3	0.2	0.2	0.1
NL_of_which_spillover	0.4	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.1	0.1	0
NL_low_productivity	0.3	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0
AT_baseline	0.6	0.8	0.9	0.9	0.8	0.6	0.5	0.4	0.4	0.3	0.2
AT_of_which_spillover	0.4	0.6	0.6	0.6	0.6	0.4	0.3	0.2	0.2	0.2	0.1
AT_low_productivity	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.1
PL_baseline	1	2	2.1	2.3	1.6	1	1	1	1	0.9	0.6
PL_of_which_spillover	-0.5	-0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
PL_low_productivity	0.7	1.5	1.5	1.6	0.9	0.3	0.3	0.4	0.4	0.4	0.2
PT_baseline	1.5	2.6	2.7	2.9	2.2	1.4	1.5	1.6	1.6	1.5	0.9
PT_of_which_spillover	0.4	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.1
PT_low_productivity	1.2	2.1	2	2.1	1.2	0.4	0.5	0.6	0.6	0.6	0.4
RO_baseline	1.7	3.2	3.4	3.7	2.6	1.5	1.6	1.6	1.6	1.6	1
RO_of_which_spillover	-0.6	-0.3	0	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
RO_low_productivity	1.2	2.4	2.4	2.6	1.4	0.3	0.5	0.5	0.6	0.6	0.4
SI_baseline	1.1	2	2	2.1	1.5	0.9	0.9	0.9	0.9	0.8	0.5
SI_of_which_spillover	0.5	0.7	0.8	0.8	0.7	0.5	0.4	0.3	0.2	0.2	0.1
SI_low_productivity	0.9	1.5	1.5	1.5	0.9	0.3	0.3	0.3	0.3	0.3	0.2
SK_baseline	1.6	2.5	2.6	2.7	1.8	1.1	1.1	1.1	1.1	1.1	0.6
SK_of_which_spillover	0.6	0.8	0.8	0.8	0.7	0.6	0.4	0.3	0.2	0.2	0.1
SK_low_productivity	1.2	2	1.9	1.9	1	0.2	0.3	0.4	0.4	0.4	0.2
FI_baseline	0.6	0.8	0.8	0.8	0.6	0.4	0.4	0.3	0.3	0.3	0.1
FI_of_which_spillover	0.4	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0
FI_low_productivity	0.3	0.4	0.4	0.5	0.4	0.2	0.2	0.2	0.1	0.1	0
SE_baseline	0.1	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1
SE_of_which_spillover	-0.1	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SE_low_productivity	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0
EU_baseline	0.8	1.4	1.4	1.5	1.2	0.8	0.8	0.8	0.7	0.7	0.4
EU_of_which_spillover	0.3	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1
EU_low_productivity	0.6	1.0	1.0	1.0	0.7	0.3	0.3	0.3	0.3	0.3	0.2

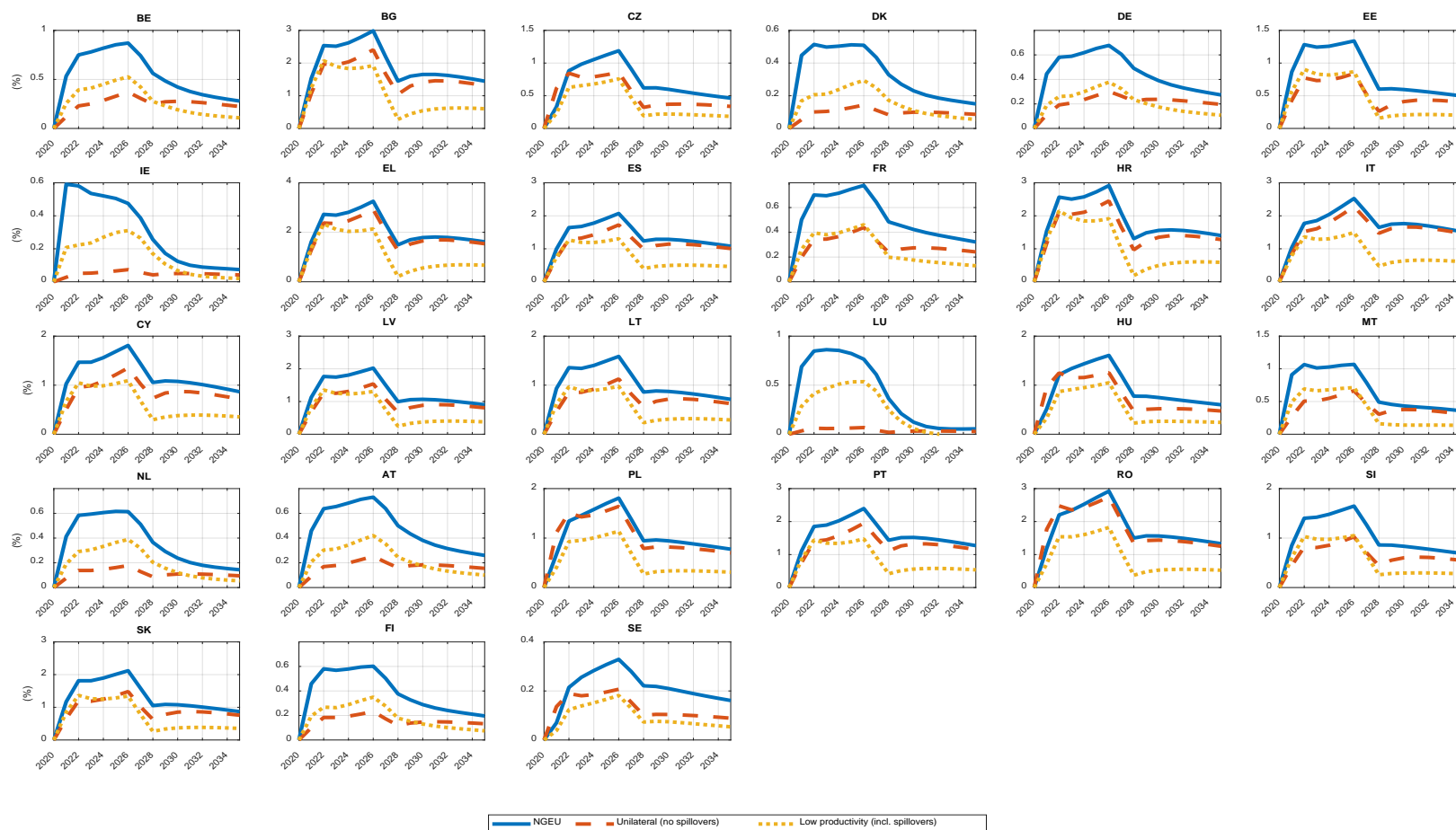
Note: This table reports the level of real GDP in per cent deviation from a no-policy change baseline. For each MS, the first line (“\_baseline”) reports the GDP effects for the baseline model including spillover, the second line (“\_of\_which\_spillover”) reports the contribution of NGEU spillover, while the last line (“\_low\_productivity”) displays results from a low productivity scenario including spillover. Note that, in the low productivity scenario, the smaller growth effects in each MS also reduce the spillover. These results are based on stylised assumptions regarding the nature of the investment and its time profile. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Graph 11.1. GDP effects by MS (fast profile)



Note: This graph reports the level of real GDP in per cent deviation from a no-policy change baseline. For each MS, the blue line reports the GDP effects for the synchronised NGEU including spillover, the red (dashed) line reports the unilateral effects (absent spillover), while the yellow (dotted) line displays results from a low productivity scenario including spillover. Note that, in the low productivity scenario, the smaller growth effects in each MS also reduce the spillover. These results are based on stylised assumptions regarding the nature of the investment and its time profile. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Graph 11.2. GDP effects by MS (six-year profile)



Note: This graph reports the level of real GDP in per cent deviation from a no-policy change baseline. For each MS, the blue line reports the GDP effects for the synchronised NGEU including spillover, the red (dashed) line reports the unilateral effects (absent spillover), while the yellow (dotted) line displays results from a low productivity scenario including spillover. Note that, in the low productivity scenario, the smaller growth effects in each MS also reduce the spillover. These results are based on stylised assumptions regarding the nature of the investment and its time profile. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

## 12. APPENDIX G: Debt dynamics, expenditure rules and NGEU financing assumptions

Graph 12.1 presents the simulated debt-to-GDP ratios for all MS. The graphs show that the national debt ratios (excluding EU debt) fall for all MS. The debt dynamics also remain favourable when explicitly accounting for EU debt (based on GDP shares). Notably, these results depend on the assumed government expenditure rules and the assumed NGEU financing.

**Expenditure rules.** Regarding expenditure rules, we can distinguish two broad alternative assumptions depending on whether non-NGEU government spending (e.g. transfers and government expenditure) (i) remains constant in real terms or (ii) is indexed to GDP. The simulated debt ratios presented in Graph 4.5 (see above) and Graph 12.1 are based on the latter assumption, i.e. transfers (e.g. pensions) and government expenditure (e.g. public wages) increase in line with GDP. In this case, the medium-run debt ratio reduction is relatively smaller because higher spending also increases the debt level. By contrast, the alternative assumption of constant spending would imply a larger medium-run reduction in the debt ratio because non-NGEU government spending remains constant while GDP grows.<sup>38</sup>

**NGEU financing.** The debt dynamics also depend on the assumed financing of the repayments for RRF loans and grants. Graph 12.2 below shows our detailed NGEU financing assumptions for all MS. In particular, the graph depicts the assumed grants (blue) and, where applicable, loans (red dotted) received in 2021-26. It also shows the assumed national contributions to the EU budget to repay the NGEU debt (yellow) and the loan repayment (purple dotted) based on the following stylised assumptions:

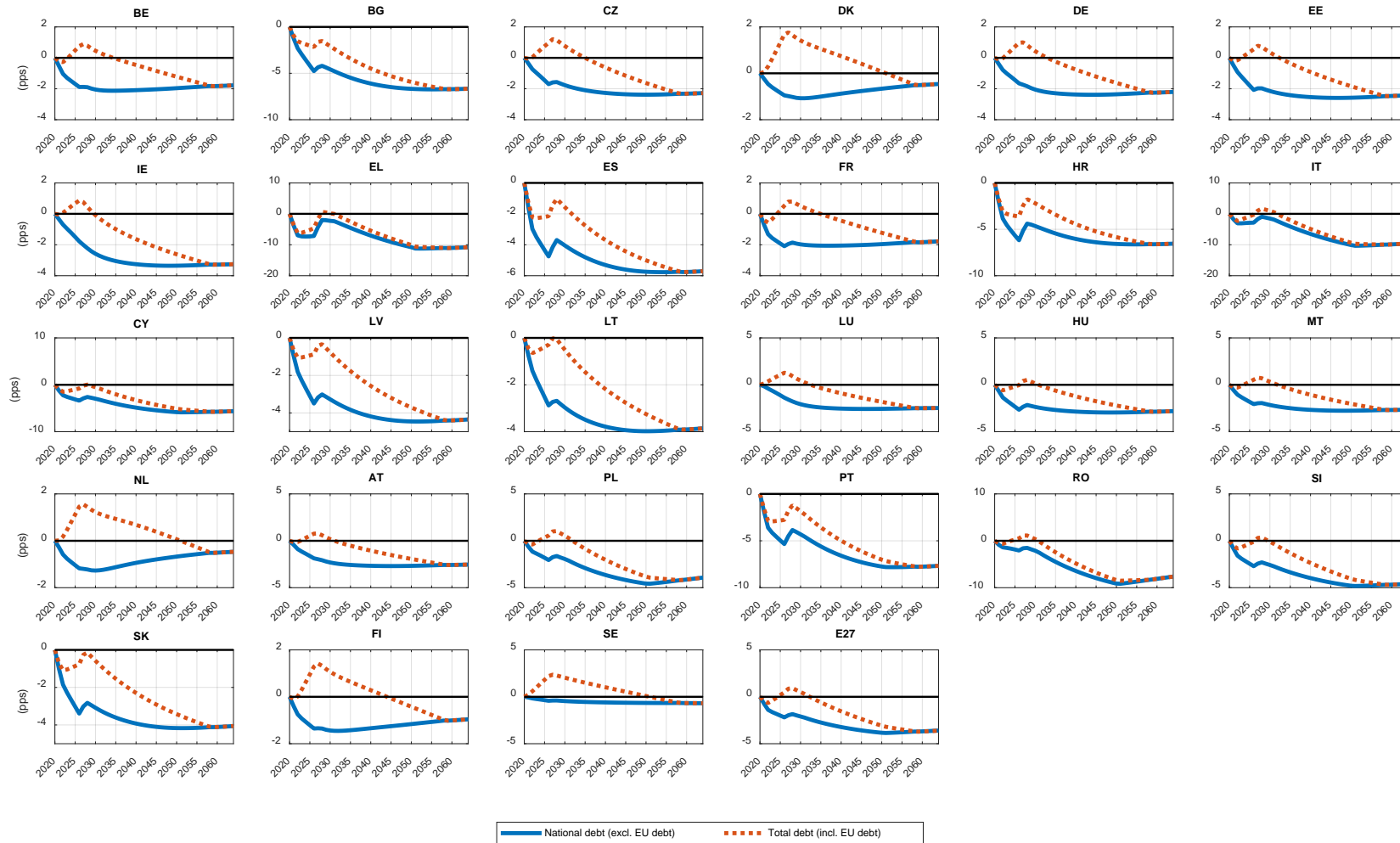
- *Grants:* The repayment of NGEU debt to finance grants is assumed to occur later (2027 to 2058), with all MS contributing to the EU budget according to their current GDP shares.<sup>39</sup>
- *Loans:* The principal loan repayments take place from 2031 to 2050 (resulting in a weighted average maturity of around 20 years).
- *Linear profile:* All repayments and contributions follow a linear profile with equal payments across years.
- *Financed via lump-sum taxes:* It is assumed that lump-sum taxes finance all repayments, implying an improvement of the primary balance with respect to the no-policy change baseline over that period, in particular given our additionality assumptions.

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<sup>38</sup> To take a conservative stance, GDP results presented in the main text and Appendix F are based on constant government spending. In this case, GDP increases relatively less because there is no additional stimulus from higher transfers and government expenditure.

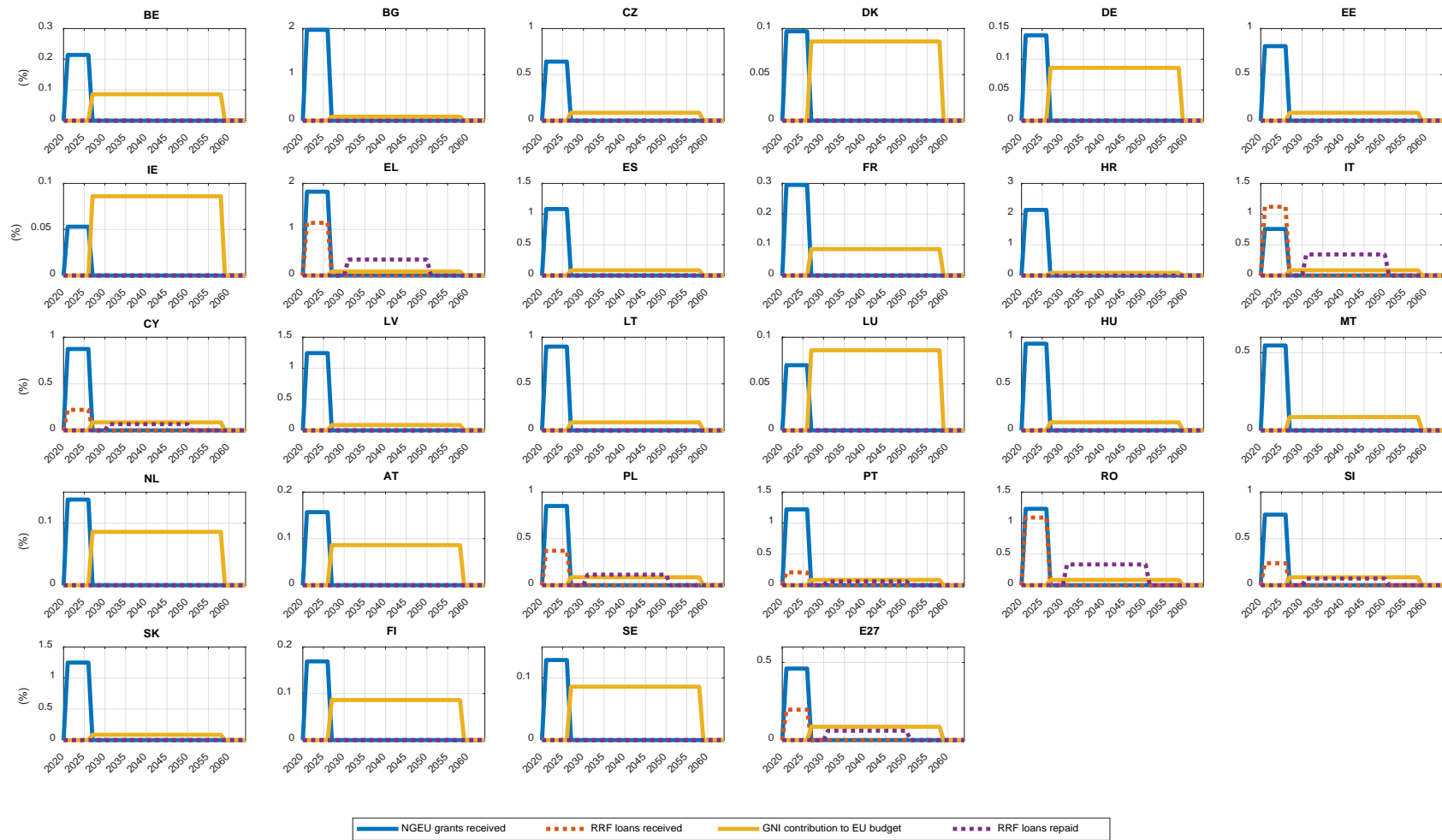
<sup>39</sup> Thus, we abstract from future changes in the GNI-shares or own EU resources (Section 2.3).

Graph 12.1. Simulated debt ratios (in pps deviation from baseline), for modelling purposes only.



Note: This graph reports the debt-to-GDP ratios in percentage point deviation from a no-policy change baseline. These profiles are based on scenarios in which government spending is linked to GDP. Note that these model-based debt projections can differ from the Commission's Debt Sustainability Assessment which follows a different methodology. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).

Graph 12.2. Assumed grants, loans received, and contributions paid, per MS (% of GDP), for modelling purposes only.



Note: This graph reports the received volumes of NGEU grants (blue), RRF loans (red dotted), GNI contributions to the EU budget (yellow), which finances grant volumes, and the repayment of loans (purple dotted) for all MS. Two-letter country codes follow EU conventions ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country\\_codes](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes)).





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