ONLINE APPENDIX

Quantifying Spillovers of Coordinated Investment Stimulus in the EU

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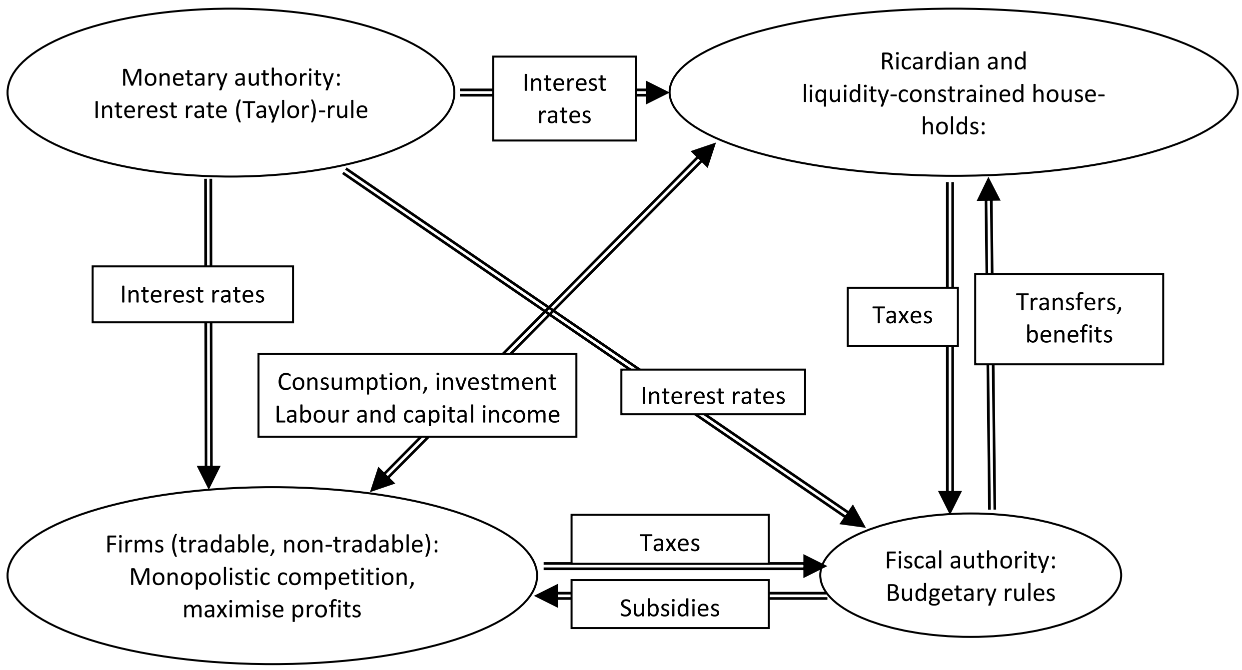
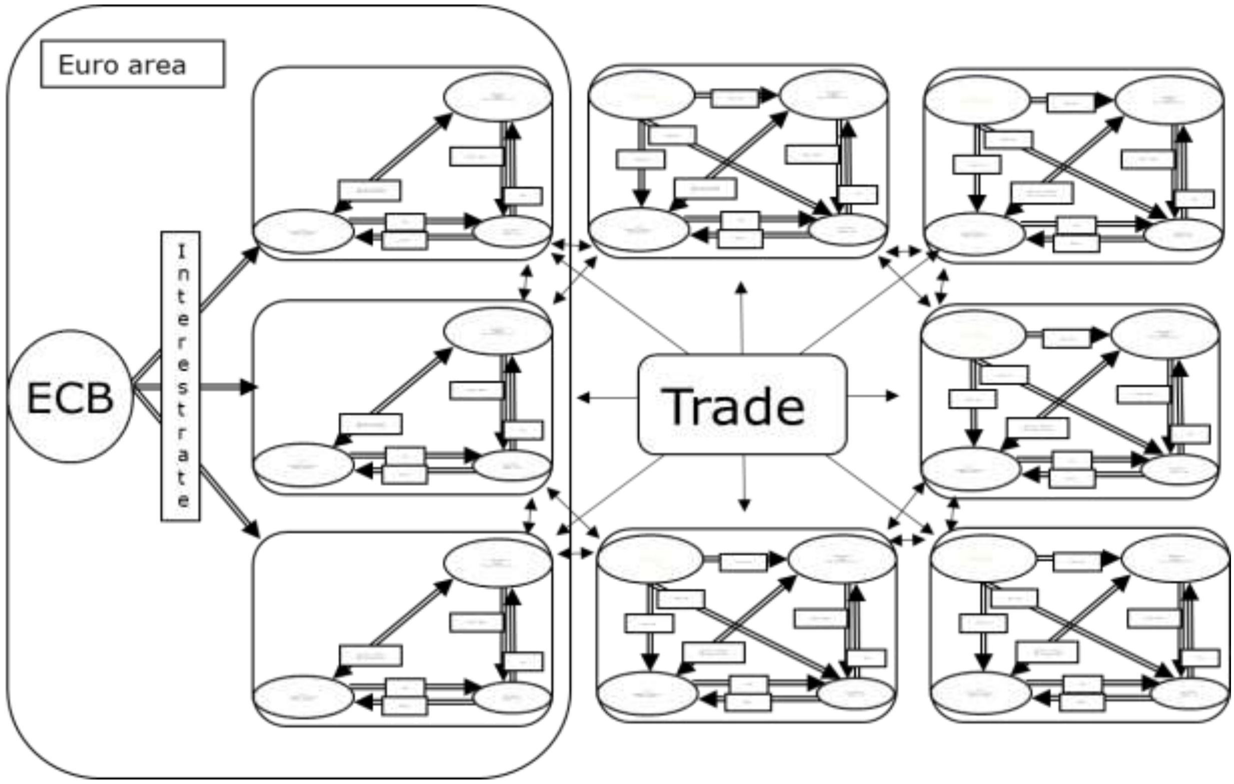
A. MODEL OVERVIEW

Graph A.1. **Basic structure of QUEST model regions**



The model includes 28 isomorphic geographical regions (all EU Member States and the rest of the world). Graph A.1 sketches the basic structure of the regional blocks and Graph A.2 shows the interlinked regional blocks with trade. For euro-area countries, the European Central Bank (ECB) sets the monetary policy.

Graph A.2. **Multicountry structure of QUEST model regions**



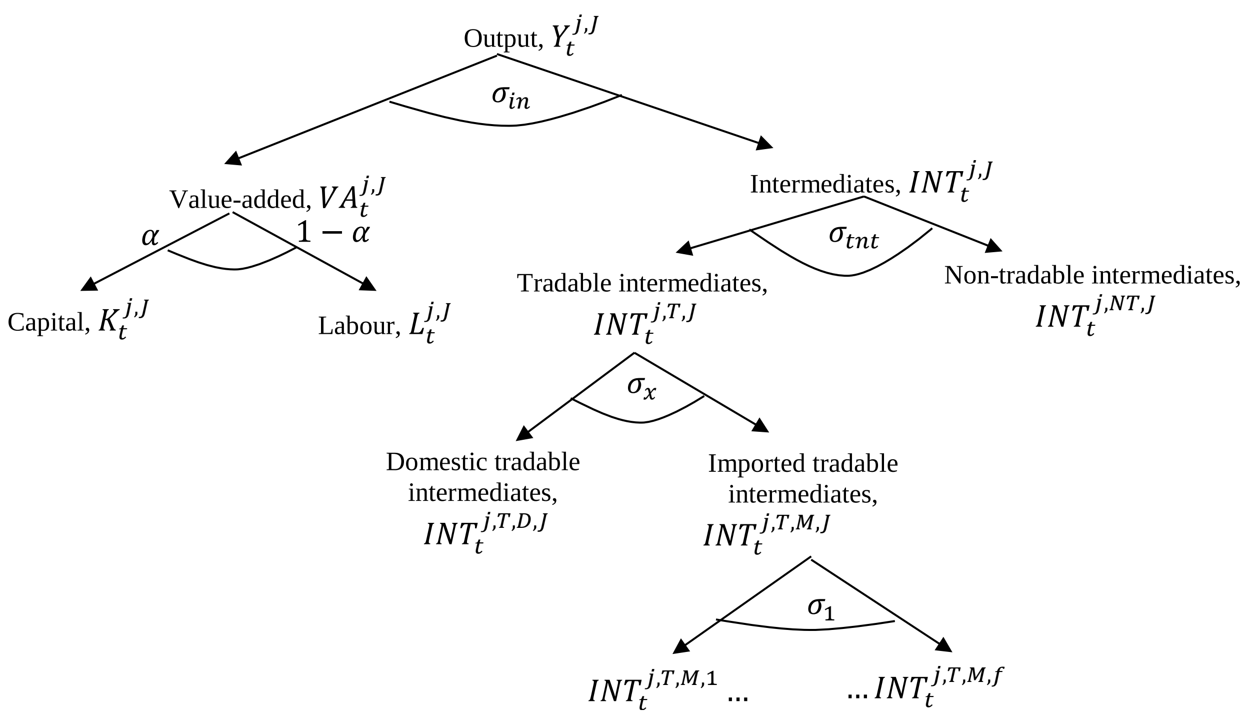
B. MODEL DERIVATION

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 (except for monetary policy).

B.1 PRODUCTION

Graph B.1 shows the nested structure for production with the corresponding elasticities for a stylised review of our model structure:

Graph B.1. **The production nesting scheme**



Each region is home to a tradable and 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 Y_t^J with $J \in \{T, NT\}$ is a CES aggregate of the varieties $Y_t^{j,J}$:

$$Y_t^J \equiv \left(\int_0^1 (Y_t^{j,J})^{(\sigma_J - 1)/\sigma_J} dj \right)^{\sigma_J/(\sigma_J - 1)} \qquad \text{B.1}$$

where σ_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 their total output to domestic and foreign private households and governments in the form of consumption and investment goods, and in the form of intermediate inputs to domestic and foreign private firms. The NT sector sells its total output as consumption goods to the domestic households, in the form of consumption and investment goods to the domestic government, and as intermediate inputs to domestic firms. Hence, all private investment in physical capital consists of T goods. For simplicity, the rest of this subsection does not explicitly distinguish sector indices (*J*) because the same set of equations describes both sectors.

Output is produced with a CES technology that combines value-added (VA_t^j) and intermediate inputs (INT_t^j). It nests a Cobb-Douglas technology with capital (K_t^j), production workers (L_t^j)[2] and public capital (KG_t) for the production of Y_t^j:

$$Y_t^j = \left((1 - s_{in}^j)^{\frac{1}{\sigma_{in}}} (VA_t^j)^{(\sigma_{in}-1)/\sigma_{in}} + (s_{in}^j)^{\frac{1}{\sigma_{in}}} (INT_t^j)^{(\sigma_{in}-1)/\sigma_{in}} \right)^{\sigma_{in}/(\sigma_{in}-1)} \quad \text{B.2}$$

$$VA_t^j = A_t^j (u_t^j K_t^j)^{1-\alpha} (L_t^j)^{\alpha} (KG_t)^{\alpha_g} \quad \text{B.3}$$

where s_{in}^j and σ_{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.[3] Firm-level employment L_t^j is a CES aggregate of the labour services supplied by individual households *i*:

$$L_t^j \equiv \left(\int_0^1 (L_t^{i,j})^{(\theta-1)/\theta} \, di \right)^{\theta/(\theta-1)} \quad \text{B.4}$$

where θ indicates the degree of substitutability between the different labour types *i*.

[2] Our calibration allows for a fraction of overhead labour and fixed costs.

[3] 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.

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:

$$Pr_t^j = \frac{p_t^j}{p_t^J} Y_t^j - \frac{p_t^{INT,j}}{p_t^J} INT_t^j - (1 + ssc_t^J) \frac{w_t^p}{p_t^J} L_t^j - i_t^J \frac{p_t^I}{p_t^J} K_t^j - adj_t^j \qquad \text{B.5}$$

where ssc_t^J, w_t^p, i_t^J and p_t^I 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.

$$adj_t^{L,j} \equiv 0.5\gamma_L w_t^p (\Delta L_t^j)^2 \qquad \text{B.6}$$

$$adj_t^{P,j} \equiv 0.5\gamma_P (\pi_t^j)^2 P_{t-1}^j O_t^J \text{ with } \pi_t^j \equiv \frac{P_t^j}{P_{t-1}^j} - 1 \qquad \text{B.7}$$

$$adj_t^{u,j} \equiv \left(\gamma_{u,1} (u_t^j - 1) + \frac{\gamma_{u,2}}{2} (u_t^j - 1)^2\right) \frac{p_t^I}{p_t^J} K_t^J \qquad \text{B.8}$$

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 Y_t^j, the production technology (B.2) and (B.3), and the adjustment costs (B.6-B.8). The first-order conditions (FOC) are:

$$\frac{\partial \mathrm{Pr}_t^j}{\partial L_t^j} => \frac{\partial Y_t^j}{\partial L_t^j} \eta_t^j - \gamma_L w_t^p \Delta L_t^j + \gamma_L \beta E_t (\lambda_{t+1}^r / \lambda_t^r \, w_{t+1}^p \Delta L_{t+1}^j) = (1 + ssc_t^J) w_t^p \qquad \text{B.9}$$

$$\frac{\partial \mathrm{Pr}_t^j}{\partial K_t^j} => \frac{\partial Y_t^j}{\partial K_t^j} \eta_t^j = i_t^J p_t^I \qquad \text{B.10}$$

$$\frac{\partial Pr_t^j}{\partial u_t^j} => \frac{\partial Y_t^j}{\partial u_t^j} \eta_t^j = p_t^I K_t^J (\gamma_{u,1}^J + \gamma_{u,2} (u_t^j - 1)) \qquad \text{B.11}$$

$$\frac{\partial \mathrm{Pr}_t^j}{\partial p_t^j} => \eta_t^j = 1 - \frac{1}{\sigma^j} - \frac{\gamma_P}{\sigma^j} (\beta E_t (\frac{\lambda_{t+1}^r}{\lambda_t^r} \frac{Y_{t+1}^J}{Y_t^J} \pi_{t+1}^j) - \pi_t^j) \qquad \text{B.12}$$

where η_t^j is the Lagrange multiplier associated with the production technology, β is the discount factor of Ricardian households (see below) that are the firm owners, λ_t^r is their marginal value of wealth in terms of consumption as defined in (B.20) below.

Equation (B.9) implies that optimising firms equate the marginal product of labour net of adjustment costs to wage costs. The equations (B.10-B.11) jointly determine the optimal capital stock and capacity utilisation by equating the marginal product of capital to the rental price and the marginal product of capital services to the marginal cost of increasing capacity. Equation (B.12) defines the price mark-up factor as a 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:

$$\eta_t^j = \frac{\sigma^j - 1}{\sigma^j} - \frac{\gamma_P}{\sigma^j}\left(\beta E_t\left(\frac{\lambda_{t+1}^r}{\lambda_t^r}\frac{Y_{t+1}^J}{Y_t^J}\left(sfp^J E_t \pi_{t+1}^j + (1 - sfp^J)\pi_{t-1}^j\right)\right) - \pi_t^j\right) \quad \text{with } 0 \leq sfp \leq 1 \qquad \text{B.13}$$

for the inverse of the price mark-ups in the T and NT sectors. Given the symmetry of objectives and constraints across firm *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 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.

B.2 HOUSEHOLDS

The household sector consists of a continuum of households $h \in [0,1]$, partioned 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:

$$U\left(C_t^h, 1 - L_t^h\right) = (1 - h^c)log(C_t^h - h^c \bar{C}_{t-1}^h) + \omega\frac{(1 - L_t^i)^{1-\kappa}}{1 - \kappa} \qquad \text{B.14}$$

where $\kappa > 0$. Households supply differentiated types of labour services *i*, which are distributed equally over household types.[4] Unions bundle the differentiated labour services and maximise a joint utility function for each type of labour *I* (see below).

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

B.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. t_t^w and t_t^k denote the tax rates on income from labour and corporate profits, respectively. Finally, households pay lump-sum taxes, T_t^{LS}. The per-period budget constraint in real terms is given by:

$$\begin{aligned}&(1+t_t^c)p_t^C C_t^r + \sum_{J=T,NT} p_t^I I_t^J + (B_t^G + B_t^r) + rer_t B_t^{F,r} + T_t^{LS,r} - (1-t_t^k)\sum_{J=T,NT}\left(i_t^J p_t^I K_t^J + p_t^J Pr_t^J\right)\\ &-(1+r_{t-1})(B_{t-1}^G + B_{t-1}^r) - (1+r_{t-1}^F) rer_t B_{t-1}^{F,r} - (1-t_t^W) w_t^i L_t^i - ben_t^{real}\left(1-L_t^i\right) - TR_t^{real}\\ &+\sum_{J=T,NT}\left(adj_t^{K,J} + adj_t^{I,J}\right) + adj_t^{w,r},\end{aligned} \qquad \text{B.15}$$

With the following adjustment costs specifications:

$$adj_t^{K,J} \equiv 0.5\gamma_{K,J}(I_t^J/K_{t-1}^J - \delta^{K,J})^2 p_t^I \overline{K}_{t-1}^J \qquad \text{B.16}$$

$$adj_t^{I,J} \equiv 0.5\gamma_{I,J} p_t^I (\Delta I_t^J)^2 \qquad \text{B.17}$$

$$adj_t^{w,r} \equiv 0.5\gamma_W\left(\pi_t^{w,i}\right)^2 \overline{L}_t^p, \qquad \text{B.18}$$

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

$$E_t(\lambda_t^r/\lambda_{t+1}^r) = \beta(1 + r_t) \qquad \text{B.19}$$

$$\lambda_t^r = \frac{(1-h^c)^{\sigma_c}}{(1+t_t^c)p_t^C(C_t^r - h^c C_{t-1}^r)^{\sigma_c}} \qquad \text{B.20}$$

with the real interest rate $r_t \approx i_t - E_t\pi_{t+1}$, 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:

$$\gamma_{K,J}\left(\frac{I_t^J}{K_{t-1}^J}-\delta^{K,J}\right)+\gamma_{I,J}\Delta I_t^J-\gamma_{I,J}\beta E_t\left(\frac{\lambda_{t+1}^r}{\lambda_t^r}\frac{p_{t+1}^I}{p_t^I}\Delta I_{t+1}^J\right)=q_t^J-1 \qquad \text{B.21}$$

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:

$$q_t^J=i_i^J+\beta E_t\left(\frac{\lambda_{t+1}^r}{\lambda_t^r}\frac{p_{t+1}^I}{p_t^I}\left[t_{t+1}^k\delta^{K,J}-\gamma_K\left(\frac{I_{t+1}^J}{K_t^J}-\delta^{K,J}\right)\frac{I_{t+1}^J}{K_t^J}+(1-\delta^{K,J})q_{t+1}^J\right]\right) \qquad \text{B.22}$$

The FOC for investment in foreign bonds together with equation (B.19) and the approximation $\ln(1+x)\approx x$ for small values of x gives the UIP condition:

$$i_t=i_t^F+E_t\frac{\Delta e_{t+1}}{e_t}+\varepsilon_t^{rBF} \qquad \text{B.23}$$

that determines the nominal exchange rate vis-à-vis the rest of the world. There are no capital controls that would insulate domestic from international capital markets and separate domestic monetary from exchange-rate policy. Equation (B.23) contains an endogenous external risk premium $\varepsilon_t^{rBF}=-\alpha\left(\frac{e_tB_t^{F,r}}{GDP_t}-\overline{B^{F,tar}}\right)$ that depends on the net foreign asset (NFA) position ($B_t^{F,r}$) of the domestic economy relative to the target value ($\overline{B^{F,tar}}$). 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.

B.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:

$$(1+t_t^c)P_t^cC_t^l=(1-t_t^w)W_tL_t^i+TR_t+ben_t\left(1-L_t^i\right)-T_t^{LS}. \qquad \text{B.24}$$

B.2.3. Wage setting

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

$$L_t=\left(\int_0^1 {L_t^i}^{\frac{\theta-1}{\theta}}\,di\right)^{\frac{\theta}{\theta-1}} \qquad \text{B.25}$$

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

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:

$$(mrs_t)^{1-wrlag}\left(\frac{\frac{\theta-1}{\theta}(1-t_t^W)W_{t-1}-ben_{t-1}}{P_{t-1}^C}\right)^{wrlag} = \frac{\frac{\theta-1}{\theta}(1-t_t^W)W_t-ben_t}{P_t^C}$$
$$+\frac{\gamma^w}{\theta}(1+\pi_t^w)\pi_t^w - \beta E_t\left(\frac{\lambda_{t+1}^{av}}{\lambda_t^{av}}\frac{\gamma^w}{\theta}(1+\pi_{t+1}^w)\frac{L_{t+1}}{L_t}(sfw\pi_{t+1}^w+(1-sfw)\pi_{t-1}^w)\right) \quad \text{B.26}$$

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.

B.3 FISCAL POLICY

B.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).[5] Formally, public capital follows the law of motion:

$$K_t^G = (1-\delta^g)K_{t-1}^G + A_{t-N}^{IG}, \quad \text{B.27}$$

where A_{t-N}^{IG} denotes authorised investment and δ^g the depreciation rate of public capital.[6] Time-to-spend delays (Ramey, 2020) induce lags between authorised investment (appropriations) and implemented government investment following

$$I_t^G = \sum_{n=0}^{N} \psi_n A_{t-n}^{IG}, \quad \text{B.28}$$

where the parameters ψ_n, with $n \in \{0, \ldots N\}$, 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).

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[5] In particular, the standard model corresponds to Baxter and King (1993). For private investment, we maintain the standard assumptions with no additional time lags.

[6] 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.

B.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:

$$B_t^G = \left(1 + i_{t-1}^g - \pi_t\right)B_{t-1}^G + p_t^C(G_t + IG_t) + ben_t^{real}(1 - L_t) + TR_t^{real} - T_t^{LS} \\ - \sum_J \left[t_t^k\left(i_t^J p_t^I K_t^J + p_t^J Pr_t^J\right) + \left(t_t^w + ssc_t^J\right)w_t L_t^J\right] - t_t^C p_t^C C_t \\ + CO_t^{EU} - GR_t^{EU} + \omega^{EU} r_{t-1}^{g,EU} BG_{t-1}^{EU} \qquad \text{B.29}$$

where $i_t^g = \rho_{ig} i_{t-1}^g + \left(1 - \rho_{ig}\right)i_t$ 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 $r_{t-1}^g B_{t-1}^{G,EU}$ captures contributions to interest-rate payments of EU debt (see below), weigthed by the country's GDP share in the EU ($\omega^{EU} = \frac{size^n}{size^{EU}}$ for each Member State n).

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

$$\Delta T_t^{LS} = \tau^B\left(B_t^G/(4Y_t) - \overline{btar}\right) + \tau^{def} \Delta B_t^G \qquad \text{B.30}$$

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 Member States.

B.3.3. The EU budget

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

$$\Delta\, B_t^{G,EU} = \sum_{n=1}^{27} (GR_t^{n,EU} - CO_t^{n,EU}) \frac{size^n}{size^{EU}} \qquad \text{B.31}$$

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 Member States. Interest payments are covered by the Member States' governments.

B.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:

$$i_t = \rho_i^R i_{t-1} + (1-\rho_i^R)\left(\bar{r} + \pi^{tar} + \tau_\pi\left(\frac{\pi_{t,yoy}^C}{4} - \pi^{tar}\right) + \tau_y ygap_t\right), \qquad \text{B.32}$$

The central bank has an inflation target π^{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.[7] We account for accommodative monetary policy at the ZLB by allowing for regime-dependent interest-rate smoothing ρ_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 Member States participating in ERM-II, we include an exchange-rate target in the Taylor rule (B.32).

B.4 TRADE LINKAGES

At the heart of our spillover analysis is a rich trade structure linking the individual economies. We assume that private households and the government have identical preferences across goods. Let $Z = C + G + IG$ be the demand by private households and the government with preferences for T and NT goods following CES functions:

$$Z_t = \left((1-s^T)^{1/\sigma_{tnt}}(Z_t^{NT})^{(\sigma_{tnt}-1)/\sigma_{tnt}} + (s^T)^{1/\sigma_{tnt}}(Z_t^T)^{(\sigma_{tnt}-1)/\sigma_{tnt}}\right)^{\sigma_{tnt}/(\sigma_{tnt}-1)} \qquad \text{B.33}$$

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:

$$Z_t^T = \left((1-s_m)^{1/\sigma_x}(Z_t^{T,D})^{(\sigma_x-1)/\sigma_x} + s_m{}^{1/\sigma_x}(Z_t^{T,M})^{(\sigma_x-1)/\sigma_x}\right)^{\sigma_x/(\sigma_x-1)} \qquad \text{B.34}$$

The elasticity of substitution between the bundles of NT versus T goods is σ_{tnt}. The elasticity of substitution between the bundles of domestically produced versus imported T goods is σ_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:[8]

[7] We define $ygap_t = \alpha \ln(\frac{L_t}{L_t^{SS}}) + (1-\alpha)\ln(\sum_J \frac{Y_t^J}{Y_t}\frac{ucap_t^J}{ucap_t^{SS,J}})$, where L_t^{SS} and $ucap_t^{SS}$ are moving averages of employment and capacity utilisation rates.

[8] The assumption of all investment goods being composed of tradable investment is a simplification but it accounts for the observation that the content in tradable goods and imports is substantially higher for private investment compared to

$$I_t^J = \left((1-s_m)^{1/\sigma_x}(I_t^{J,D,T})^{(\sigma_x-1)/\sigma_x} + s_m{}^{1/\sigma_x}(I_t^{J,M,T})^{(\sigma_x-1)/\sigma_x}\right)^{\sigma_x/(\sigma_x-1)},. \quad \text{B.35}$$

The CES aggregate (B.33) combining T and NT goods gives the following demand functions:

$$Z_t^T = s^T(P_t^T/P_t^C)^{-\sigma_{tnt}}(C_t + G_t + IG_t)\ , \quad \text{B.36}$$

$$Z_t^{NT} = (1-s^T)(P_t^{NT}/P_t^C)^{-\sigma_{tnt}}(C_t + G_t + IG_t), \quad \text{B.37}$$

The intermediate inputs in sector $J \in \{T, NT\}$ are also composites of T and NT analogously to equations (B.33) and (B.34), with T being domestically produced or imported:

$$\boldsymbol{INT_t^J = \left((1-s_{int}^J)^{1/\sigma_{tnt}}(INT_t^{NT,J})^{(\sigma_{tnt}-1)/\sigma_{tnt}} + (s_{int}^J)^{1/\sigma_{tnt}}(INT_t^{T,J})^{(\sigma_{tnt}-1)/\sigma_{tnt}}\right)^{\frac{\sigma_{tnt}}{\sigma_{tnt}-1}}} \quad \textbf{B}.38$$

$$\boldsymbol{INT_t^{T,J} = \left((1-s_m)^{1/\sigma_x}(INT_t^{T,J,D})^{(\sigma_x-1)/\sigma_x} + s_m{}^{1/\sigma_x}(INT_t^{T,J,D})^{(\sigma_x-1)/\sigma_x}\right)^{\frac{\sigma_x}{\sigma_x-1}}}. \quad \text{B.39}$$

This gives demand functions for T and NT intermediates analogously to (B.36 and B.37):

$$INT_t^{T,J} = s_{int}^J(P_t^T/P_t^{INT,J})^{-\sigma_{tnt}}INT_t^J \quad \text{B.40}$$

$$INT_t^{NT,J} = (1-s_{int}^J)(P_t^{NT}/P_t^{INT,J})^{-\sigma_{tnt}}INT_t^J \quad \text{B.41}$$

The price index, $P_t^{T,H}$ for the bundle of tradable goods for each demand category $H \in \{Z^T, I^T, I^{NT}, INT^{T,T}, INT^{T,NT}\}$ is:

$$P_t^{T,H} = \left((1-s_m)(P_t^{T,D})^{1-\sigma_x} + s_m(P_t^M)^{1-\sigma_x}\right)^{1/(1-\sigma_x)}, \quad \text{B.42}$$

where $P_t^{T,D}$ and P_t^M denote the price of the domestically produced and imported tradable goods respectively.

Import demand by demand components follows

$$M_t^H = s_m\left(\frac{P_t^{T,D}}{P_t^M}\right)^{\sigma_x} H_t,$$

where $M_t^H \in \{Z_t^{T,M}, I_t^{T,M}, I_t^{NT,M}, INT_t^{T,T,M}, INT_t^{T,NT,M}\}$ and B.43

$H_t \in \{Z_t^T, I_t^T, I_t^{NT}, INT_t^{T,T}, INT_t^{T,NT}\}$.

Total imports are the sum of imports by component:

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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 indirectly enter the production of investment goods.

$$M_t = \sum_H M_t^H \qquad \text{B.44}$$

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

$$M_t = \left(\sum\nolimits_f (s^f)^{\frac{1}{\sigma_1}} M_t^{f\,\frac{\sigma_1 - 1}{\sigma_1}}\right)^{\frac{\sigma_1}{\sigma_1 - 1}} \qquad \text{B.45}$$

where σ_1 is the elasticity of substitution between imports of different origins (M_t^f), 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:

$$M_t^f = s^f \left(\frac{P_t^{M,f}}{P_t^M}\right)^{-\sigma_1} M_t. \qquad \text{B.46}$$

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 export goods using a linear technology. Prices are sticky in the currency of the importer, so that the 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:

$$P_t^M = sfpm\, P_{t-1}^M + (1 - sfpm)\left(\sum\nolimits_f s^f \left(\frac{e_t P_t^{X,f}}{e_t^f}\right)^{1-\sigma_1}\right)^{\frac{1}{1-\sigma_1}} \qquad \text{B.47}$$

where e_t is the nominal exchange rate w.r.t. the rest of the world currency and $sfpm$ 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:

$$X_t = \sum_f X_t^f \qquad \text{B.48}$$

Aggregate export prices are a weighted average over bilateral import prices in export destinations, $P_t^{M*,f}$, adjusted by foreign countries' tariffs, $t_t^{*,f}$, and the bilateral exchange rate:

$$P_t^X = \left(\sum_f \frac{P_t^{M*,f}}{(1 + t_t^{*,f}) e_t^f} X_t^f\right) / X_t \qquad \text{B.49}$$

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

$$TOT_t \equiv P_t^X / P_t^M \qquad \text{B.50}$$

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

$$TB_t \equiv \sum_f \frac{P_t^{M*,f}}{(1+t_t^{*,f})e_t^f} X_t^f - \sum_f \frac{P_t^{M,f}}{1+t_t^f} M_t^f \quad \text{B.51}$$

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

$$\frac{CA_t}{P_t} \equiv r_{t-1}^F rer_t B_{t-1}^F + \frac{TB_t}{P_t} - CO_t^{EU} + GR_t^{EU} \quad \text{B.52}$$

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.

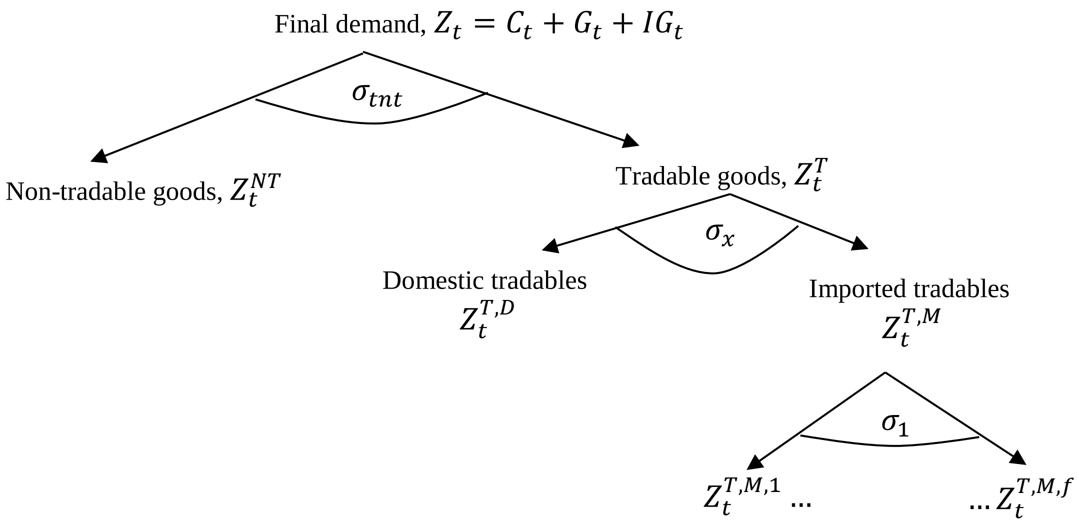
The law of motion for the NFA position is:

$$rer_t B_t^F = (1 + r_{t-1}^F) rer_t B_{t-1}^F + \frac{TB_t}{P_t} - CO_t^{EU} + GR_t^{EU} \quad \text{B.53}$$

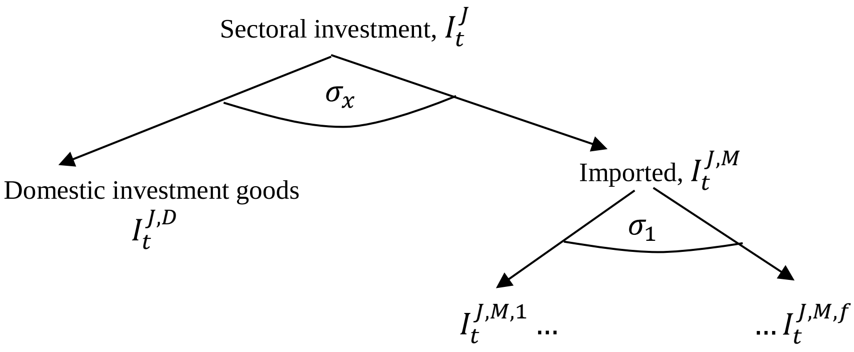
The focus on the NFA position does not take into consideration the valuation effects on gross foreign assets or liabilities that otherwise could affect the financial wealth of domestic households.

Finally, Graphs B.2-4 show the nested structure of final and intermediate demand for domestic and imported goods described above.

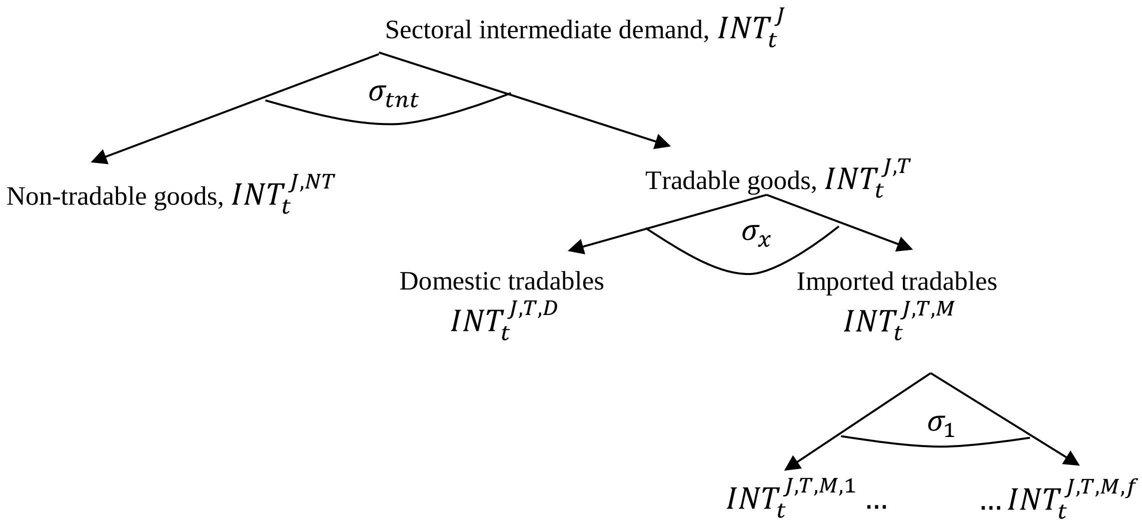
Graph B.2. **Final demand nesting scheme: private and public consumption, and public investment**



Graph B.3. **Final demand nesting scheme: private investment**



Graph B.4. **Intermediate demand nesting scheme**



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 data, 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 (ρ_i^{NoZLB}) are adopted from Ratto et al. (2009) and Albonico et al. (2019). 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). The labour supply elasticity is set at 0.2, in line with evidence from Chetty (2012). We calibrate the tax-rule parameters ($\tau^b$and τ^{def}) to ensure that the debt-to-GDP ratio gradually returns to its steady-state level in 20 years. Note, however, apart from contributions to the NGEU budget, we turn the debt stabilisation rule off for 50 years. This approach allows isolating the effect on the public debt.

Table C.1 summarises the common parameter values that are used across all regions.

Table C.1. **Model parameters – common values across all regions**

Parameter	Value	Description
β	0.997	Discount factor Ricardian households
h^c	0.85	Habit persistence in consumption
$1/\kappa$	0.2	Labour supply elasticity
γ_L	25	Head-count adjustment costs parameter
γ_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
γ_K	20	Capital adjustment cost
γ_I	75	Investment adjustment cost
γ^w	120	Wage adjustment cost
sfp	0.9	Share of forward looking T price setters
$sfpm$	0.5	Share of forward looking import price setters
sfw	0.9	Share of forward looking wage setters
$sfph$	1	Share of forward looking NT price setters
$wrlag$	0.9	Real wage inertia
σ_{tnt}	0.5	Elasticity of substitution T-NT
σ_x	1.2	Elasticity of substitution in total trade
σ_1	0.99	Elasticity of substitution between import sources
α	0.65	Cobb-Douglas labour parameter
α_g	0.12	Cobb-Douglas public capital stock parameter
σ_{in}	0.5	Elasticity of substitution between value added and intermediates
θ	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
δ^g	0.013	Depreciation rate public capital stock
τ^b	0.01	Tax rule parameter on debt
τ^{def}	0.1	Tax rule parameter on deficit
ρ_i^{NoZLB}	0.82	Interest-rate smoothing in Taylor rule (standard times)
ρ_i^{ZLB}	0.94	Interest-rate smoothing in Taylor rule (ZLB regime)
τ_π	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 Tables C.2 and C.3 in % of the exporting and 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 σ_{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 (σ_x) is set to 1.2 based on Ratto et al. (2009). The elasticity of substitution between imports of different origins (σ_1) is set to 0.99 which is in the range of parameter values applied in the IMF's multi-region macro models (Kumhof et al. 2010, Elekdag and Muir, 2014).

Table C.2. **The trade matrix used in the model calibration (exports)**

	BE	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE
BE	0.00	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

Note: This table 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).

Table C.3. **The trade matrix used in the model calibration (imports)**

	BE	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE
BE	0.00	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).

D. SOLUTION ALGORITHM

We solve the non-linear model by a Newton-Raphson solution algorithm as developed by Laffargue (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* non-linear 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:

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

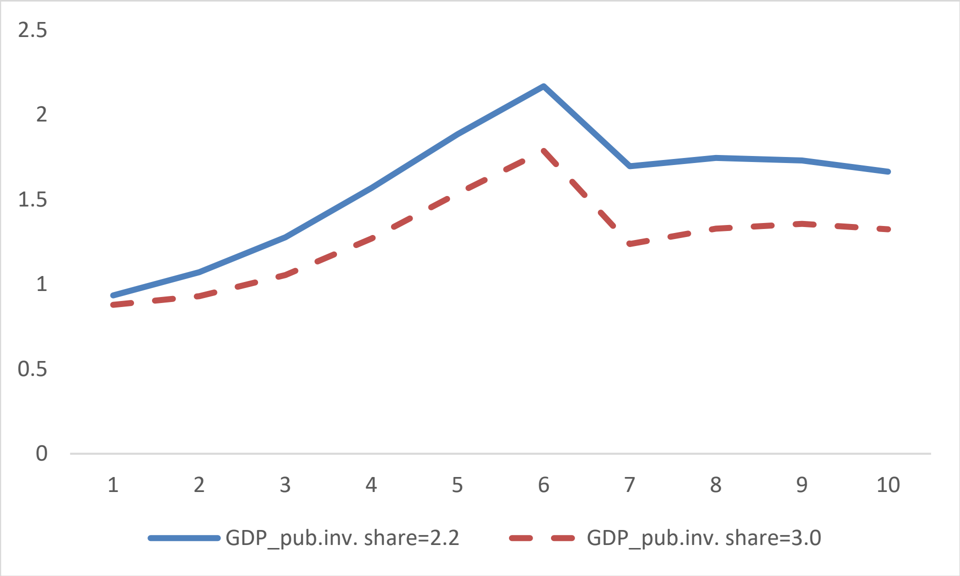
where $z_{t+j} = (y_{t+j-1}, y_{t+j}, E_t y_{t+j+1})$. This stacked system of equations is then solved with the Newton-Raphson method subject to the predetermined variables y_{t-1} and the terminal conditions y_{t+T+1}.

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 E.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 E.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.

F. DETAILED SIMULATIONS FOR ALL MEMBER STATES

Table F.1. **GDP effects NGEU by Member States (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 Member State, 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 Member State 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).

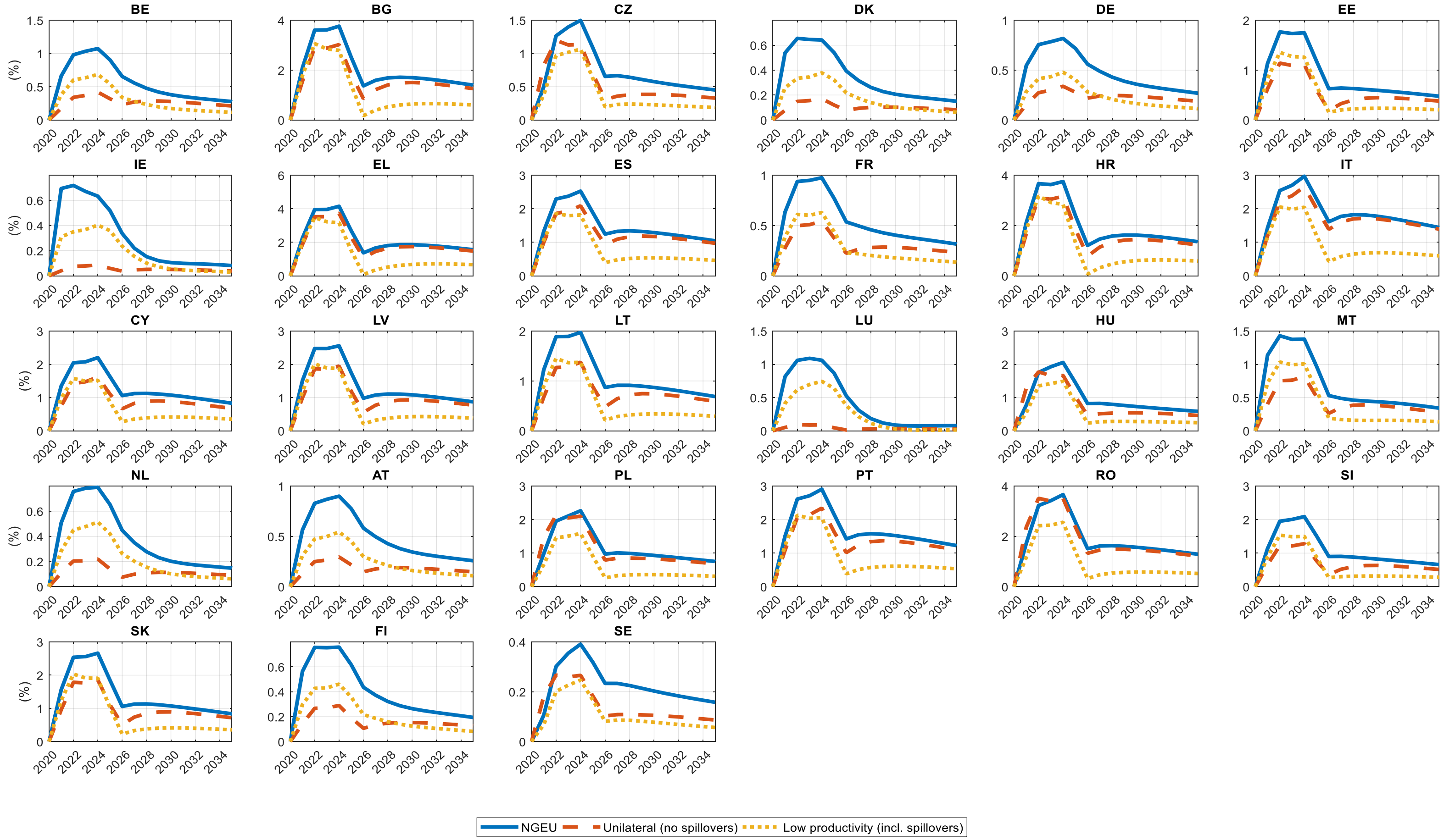
Table F.2. **GDP effects NGEU by Member States (fast profile)**

	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

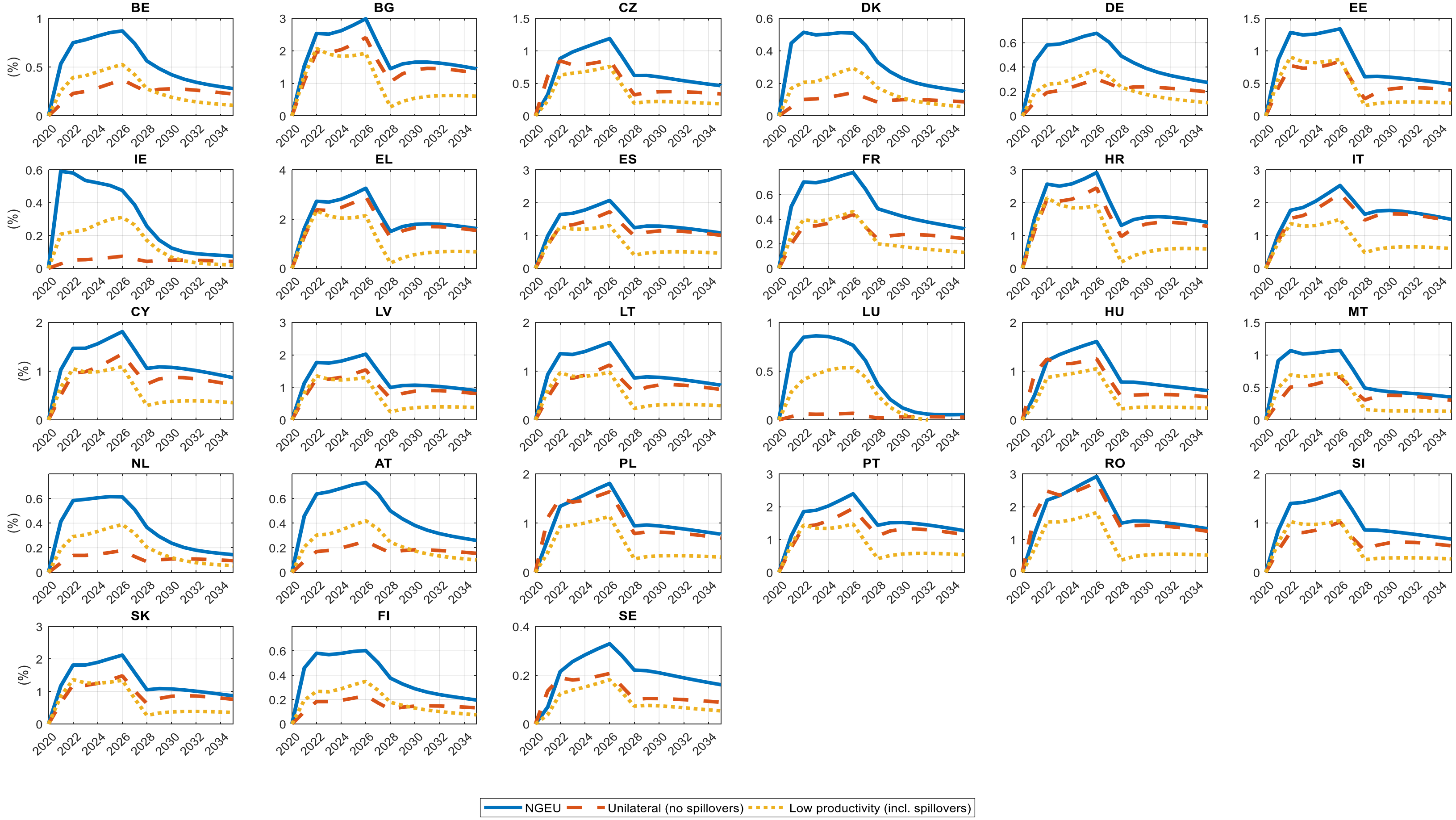
Note: This table reports the level of real GDP in per cent deviation from a no-policy change baseline. For each Member State, the first line ("_baseline") reports the GDP effects for the baseline model including spillover, the second line ("_of_which_spillover") reports the contribution of NGEU spillover, 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 Member State 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).

Graph F.1. **GDP effects by Member States (fast profile)**



Note: This graph reports the level of real GDP in per cent deviation from a no-policy change baseline. For each Member State, 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 Member State 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).

Graph F.2. **GDP effects by Member States (six-year profile)**



Note: This graph reports the level of real GDP in per cent deviation from a no-policy change baseline. For each Member State, 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 Member State 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).

G. DEBT DYNAMICS, EXPENDITURE RULES AND NGEU FINANCING ASSUMPTIONS

Graphs G.1 and G.2 present the simulated debt-to-GDP ratios for all Member States. The graphs show that the national debt ratios (excluding EU debt) fall for all Member States. The debt dynamics also remain favourable when explicitly accounting for EU debt (based on GDP shares. For some 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 G.1 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.

Notably, these results depend on the assumed government expenditure rules and the assumed NGEU financing.

Expenditure rules. Regarding expenditure rules, we can distinguish between 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 G.1 and Graph G.2 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.[9]

NGEU financing. The debt dynamics also depend on the assumed financing of the repayments for RRF loans and grants. Graph G.3 below shows our detailed NGEU financing assumptions for all Member States. 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 Member States contributing to the EU budget according to their current GDP shares.[10]

- *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.

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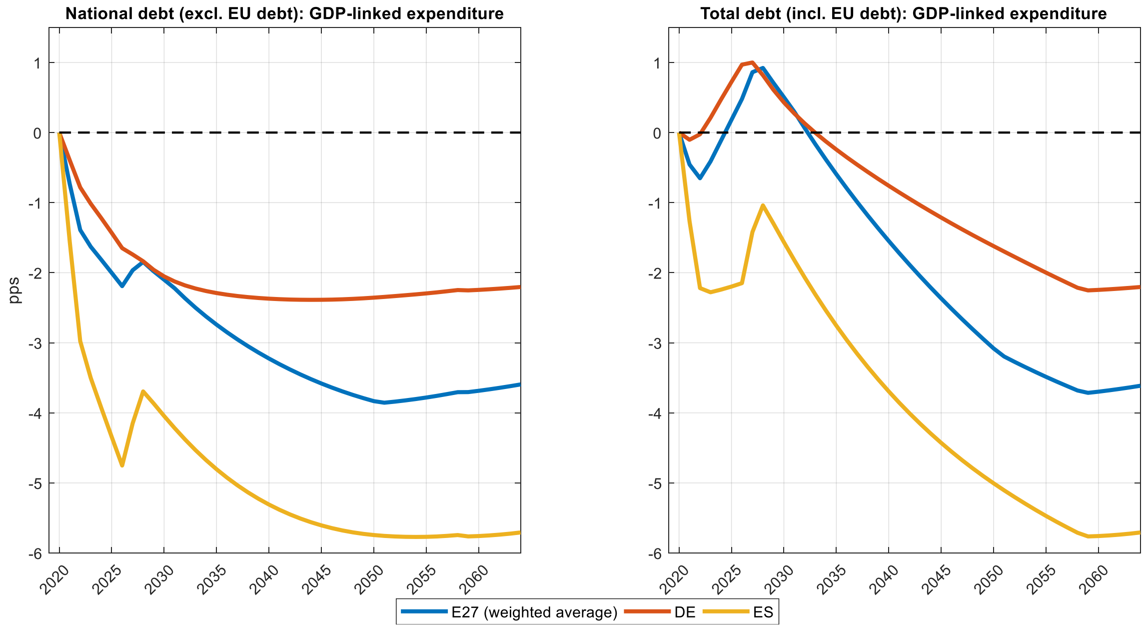
[9] To take a conservative stance, GDP results presented in the main text and Appendix F are based on constant government spending. In this case, GDP increases relatively less because there is no additional stimulus from higher transfers and government expenditure.

[10] Thus, we do not take into consideration the future changes in the GNI-shares or own EU resources (see main paper Section 3.3).

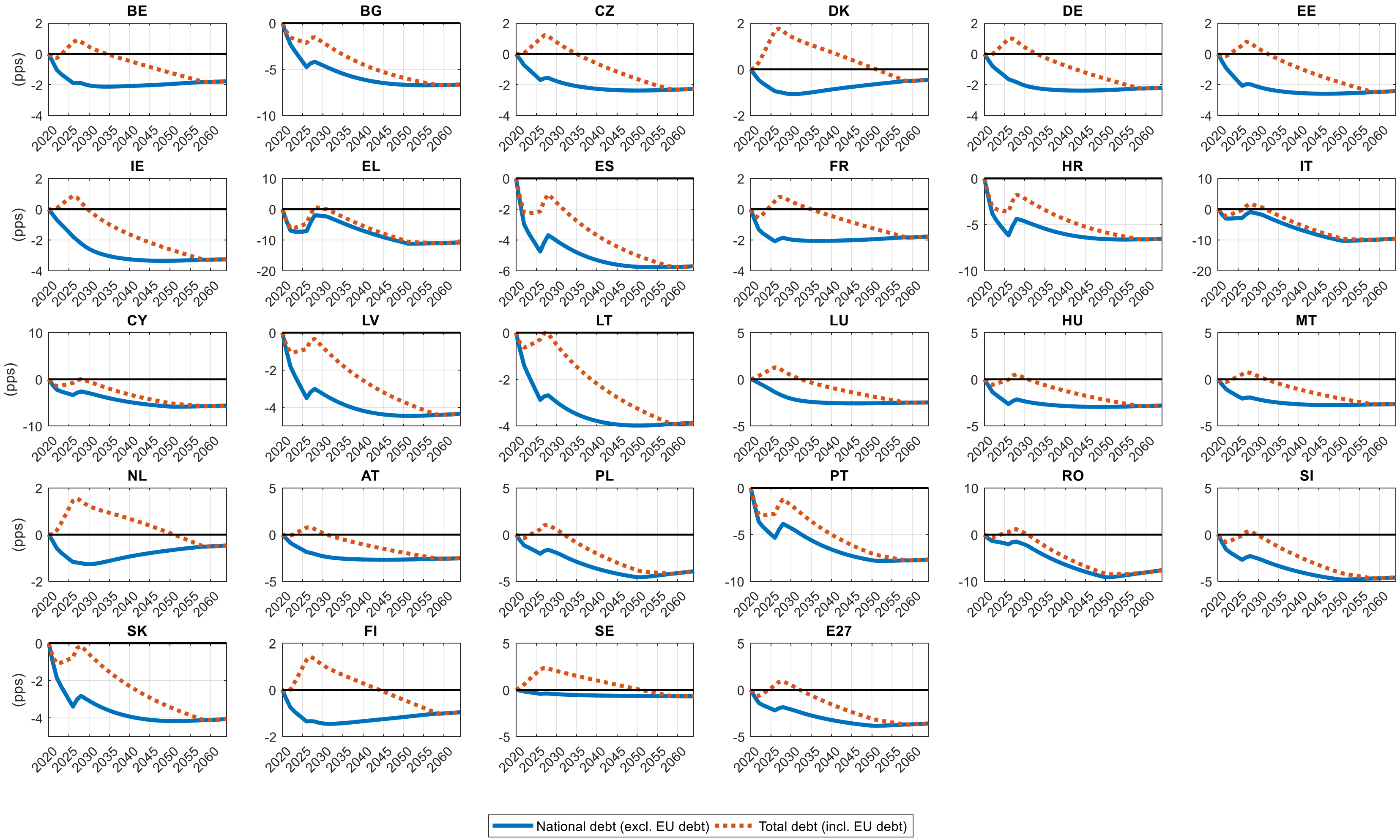
- *Financed via lump-sum taxes*: It is assumed that lump-sum taxes finance all repayments, implying an improvement of the primary balance with respect to the no-policy change baseline over that period, in particular given our additionality assumptions.

Graph G.1 **Dynamics of debt-to-GDP ratios selected countries (six year NGEU profile, high productivity)**



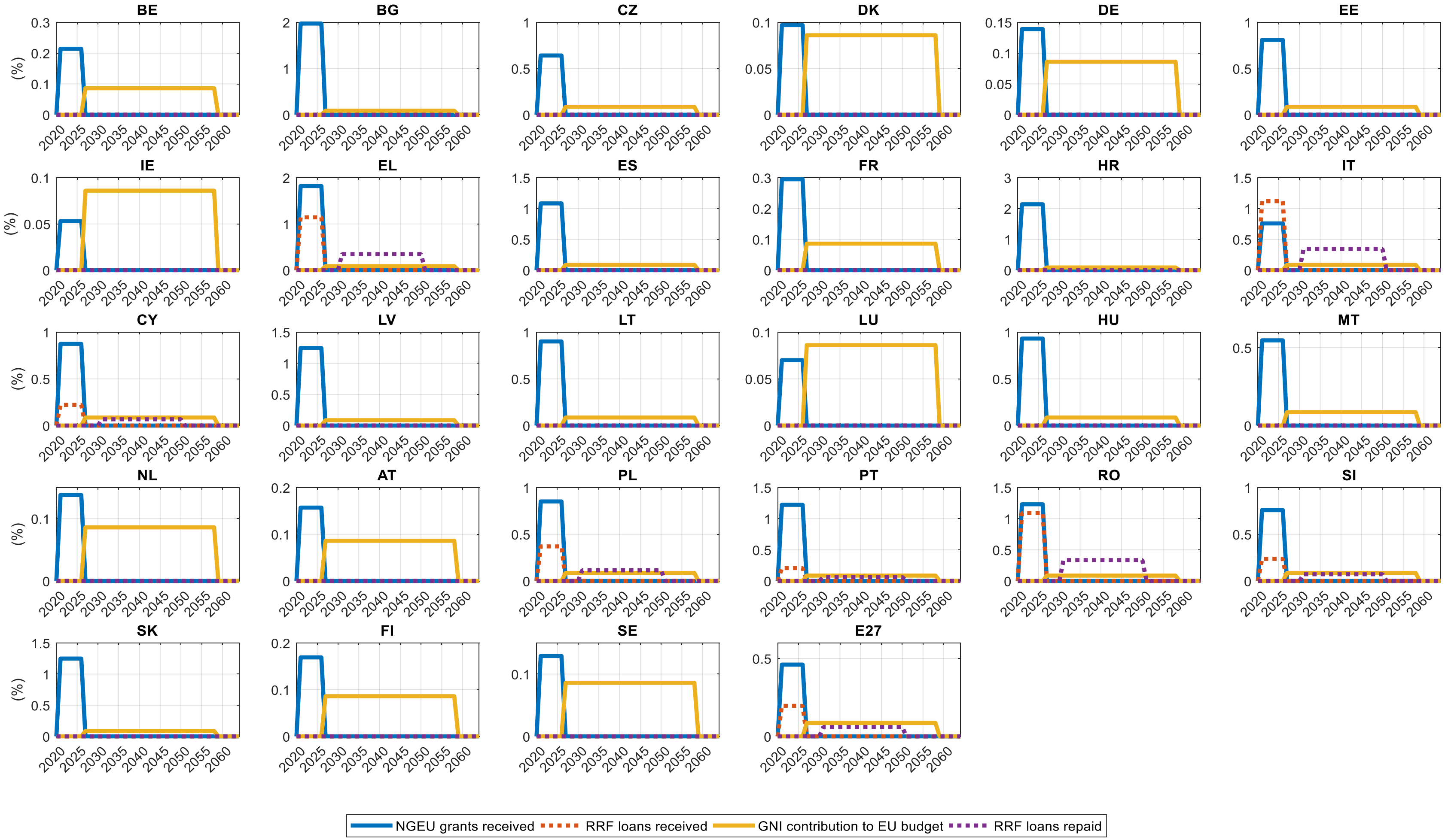
Note: This graph reports the debt-to-GDP ratios in percentage point deviation from a no-policy change baseline. These profiles are based on scenarios in which government spending is linked to GDP. Note that these model-based debt projections can differ from the Commission's Debt Sustainability Assessment 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).

Graph G.2. **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).

Graph G.3. **Assumed grants, loans received, and contributions paid, per Member State (% 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 Member States. Two-letter country codes follow EU conventions (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes).

H. FIXED EXCHANGE RATES

This Appendix presents additional stylised simulations on the role of exchange-rate dynamics for macroeconomic spillover of NGEU investment. Taking Poland as an illustrative example, we consider two regimes for all non-EA Member States, flexible and fixed (pegged) euro exchange rates, and their role in transmitting fiscal stimulus.

As discussed in the main paper, we assume that monetary policy in each currency area (c) follows a Taylor rule with a smoot interest-rate response to inflation and the output gap

$$i_{c,t} = \rho_i^R i_{c,t-1} + (1-\rho_i^R)\left(\bar{r} + \pi^{tar} + \tau_\pi\left(\frac{\pi^C_{c,t,yoy}}{4} - \pi^{tar}\right) + \tau_y ygap_{c,t}\right) + \tau_c^E(e_c - e_{EA}),$$

where e_t is the nominal exchange rate w.r.t. the rest of the world currency. Here, we add the parameter τ_c^E, which captures assumptions about the exchange-rate regime, namely:

- *Flexible exchange rates:* The baseline simulations (in the main paper) consider flexible exchange rates (i.e. $\tau^E = 0$) for all Member States outside the euro area except for Bulgaria, Croatia, and Denmark.[11]

- *Fixed exchange rates:* In this case, monetary policy stabilises the exchange rate vis-à-vis the euro area. We set ($\tau_c^E = 20$) to all EU Member States outside the euro area (EA).

Graph H.1 reports the GDP impact for the different model versions. Firstly, we consider the coordinated stimulus in all Member States (NGEU). Under fixed euro exchange rates, Member States outside the EA benefit from a sizeable currency depreciation with respect to the rest of the world (see Graph H.2). Because domestic goods prices increase less than the prices of foreign goods, the exchange-rate movement supports domestic exports. By contrast, under a flexible exchange rate, the stimulus in the other Member States generates a small effective appreciation of the domestic currency in the first year (Graph H.3 shows the nominal effective rate). Also the depreciation in the following years remains smaller compared to the fixed exchange-rate regime.

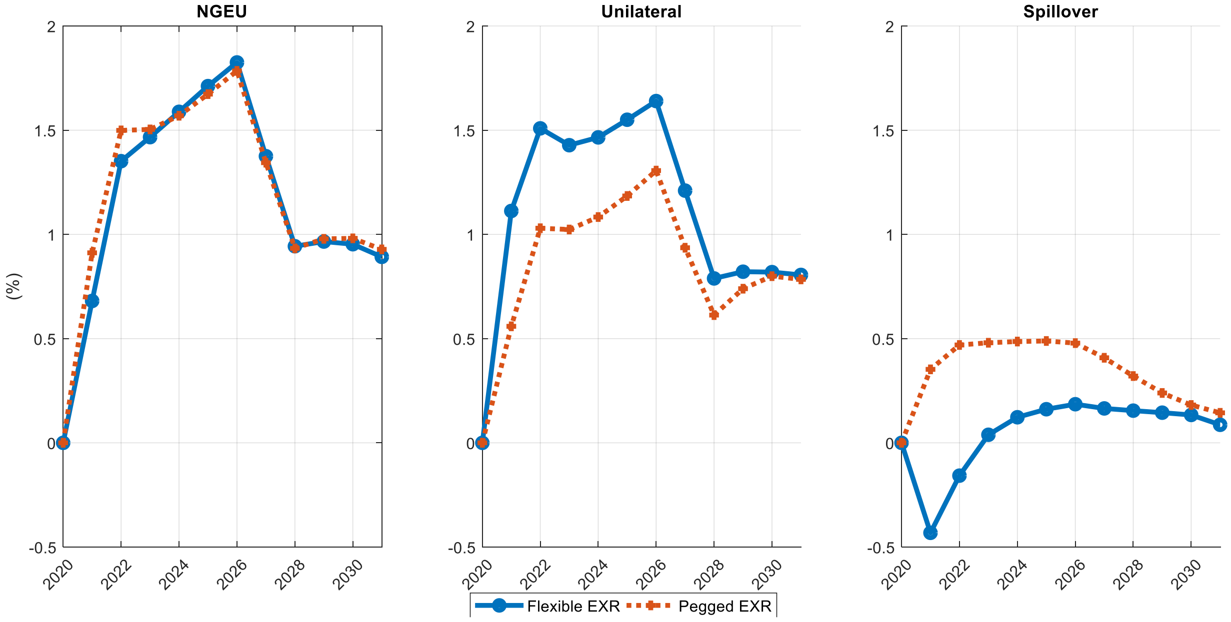
Secondly, note that this channel matters even more for a (counterfactual) unilateral stimulus. If only Poland implemented the stimulus, the beneficial depreciation, against both the EA and the rest of the world, would be large under a flexible exchange-rate regime, resulting in more significant overall GDP effects. Conversely, the unilateral effects are smaller under a fixed exchange rate (which remains constant with respect to the euro area).

Finally, note that we define GDP spillover as the difference between coordinated stimulus (NGEU) and unilateral stimulus. For a fixed exchange rate, the former is larger and the latter

[11] For these Member States participating in ERM-II, we set $\tau_c^E = 20$ to ensure almost complete stability of the euro exchange.

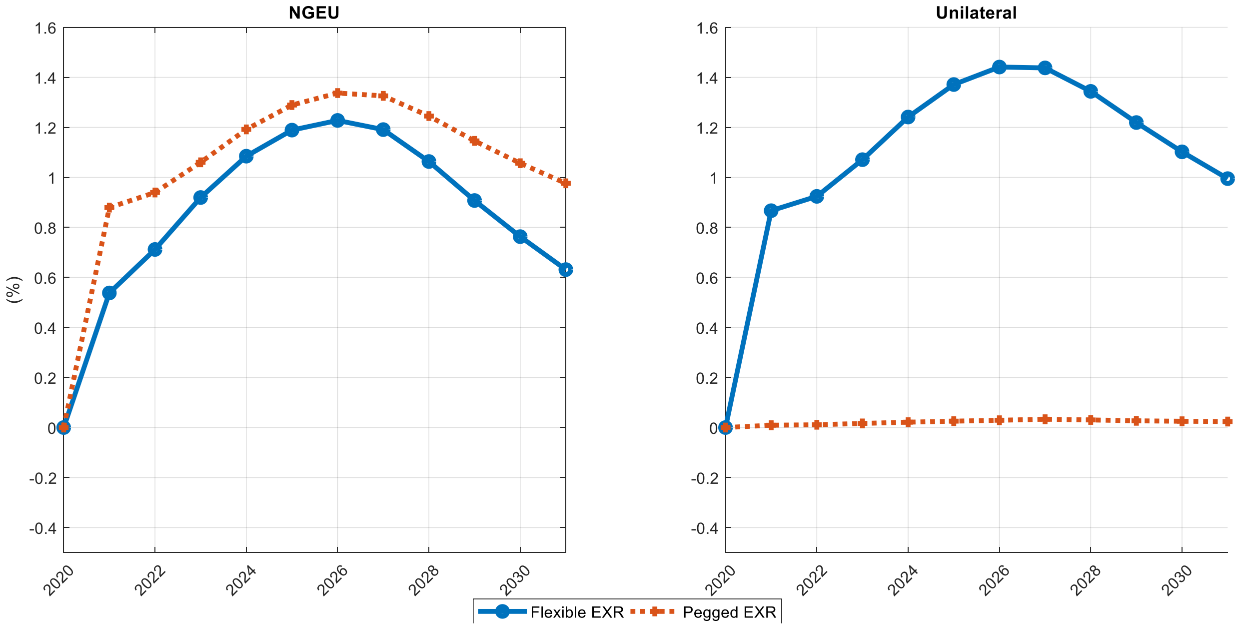
smaller. As a consequence, we find positive and sizeable spillover effects for the fixed exchange-rate regime. These additional spillover effects matter mostly in the short run.

Graph H.1. **GDP effects of NGEU (six-year profile, high productivity) across model versions**



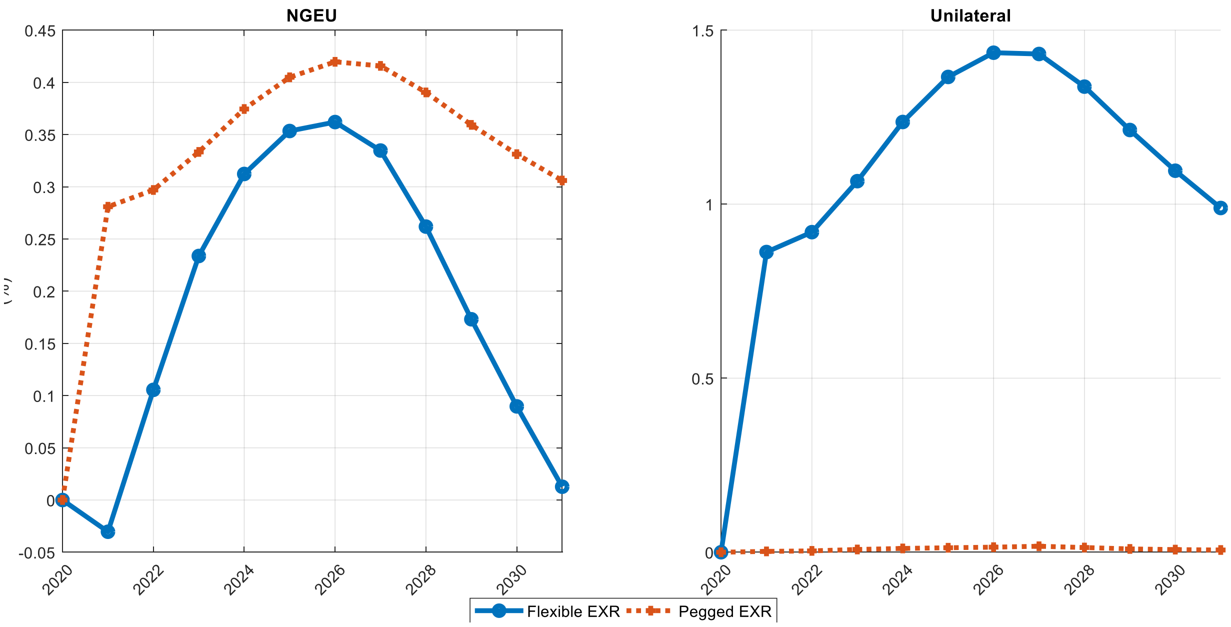
Note: This graph reports the level of real GDP in percent deviation from a no-policy change baseline for the Polish economy. Blue lines show simulation results from the baseline model with a flexible euro exchange rate. Dashed red lines display simulations under fixed exchange rates for all Member States. The simulations assume a six-year NGEU profile and high productivity of public investment.

Graph H.2. **Exchange-rate dynamics across model versions (rest-of-the world excl. EA)**



Note: This graph reports the nominal exchange rate vis-à-vis the rest-of-the world (excl. EA) in percent deviation from a no-policy change baseline for Poland. An upward movement indicates a depreciation. Blue lines show simulation results from the baseline model with a flexible exchange rate. Dashed red lines display simulations under fixed exchange rates for all Member States. The simulations assume a six-year NGEU profile and a high productivity of public investment.

Graph H.3. **Exchange-rate dynamics across model versions (nominal effective exchange rate)**



Note: This graph reports the nominal effective exchange rate in percent deviation from a no-policy change baseline for Poland. An upward movement indicates a depreciation. Blue lines show simulation results from the baseline model with a flexible exchange rate. Dashed red lines display simulations under fixed exchange rates for all Member States. The simulations assume a six-year NGEU profile and a high productivity of public investment.

I. ADDITIONAL RESULTS

This Appendix presents additional results. Section I.1 shows detailed GDP results and the breakdown into the growth effects coming from individual plans and spillover. Section I.2 illustrates the role of the output elasticity of public capital. Sections I.3 and I.4 discuss the role of labour supply elasticity and distortionary taxation, respectively.

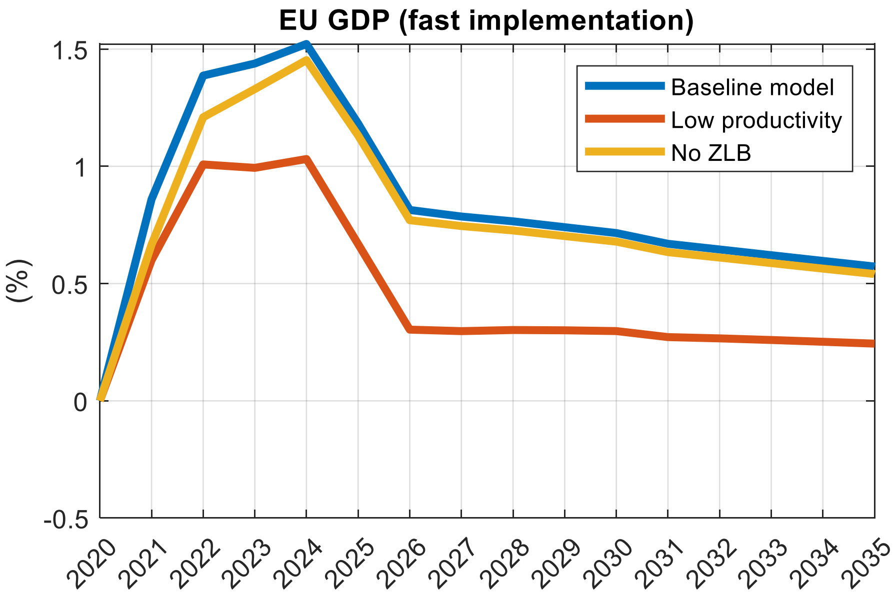
in factor and production costs and, hence, an increase (decline) in the price level of domestic output.

I.1 EFFECTS ACROSS COUNTRIES AND ALTERNATIVE ASSUMPTIONS ON NGEU

This Section presents detailed GDP results and the breakdown into the growth effects coming from individual plans and spillover. These results can be summarised as follows:

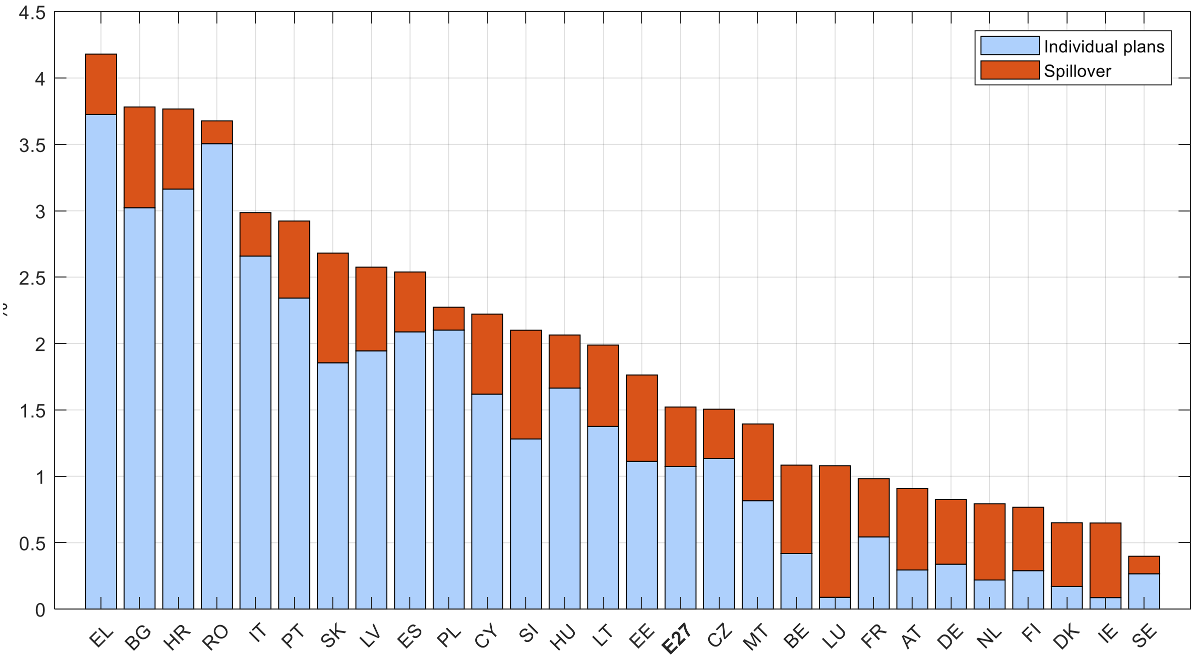
- Graph I.1 shows that the GDP peak impact is higher for the four-year scenario, while the medium and long-run effects remains similar across scenarios (low productivity, no ZLB).
- Graph I.2 and Graph I.3 show that spillover and unilateral effect are larger (smaller) for the four-year (low productivity plan).
- Similarly, Table I.1 shows that the peak spillover effects are more substantial for the fast spending (four-year) profile.
- Finally, Table I.2 reports cumulative cross-country multipliers and spillovers. The table shows how many euros each additional euro of public investment generates in each country. Note that this is implies that larger Member States see, all other things being equal, larger absolute spillovers (in euros). All results refer to long-run and undiscounted multipliers and spillovers.

Graph I.1 **Sensitivity (four-year NGEU profile, high productivity)**



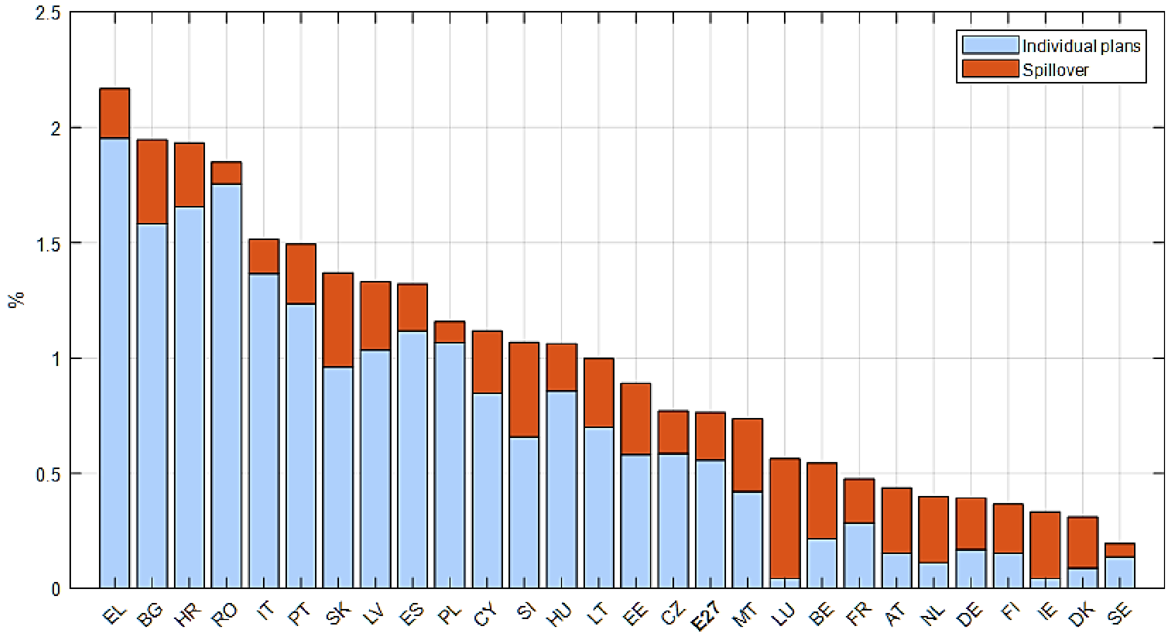
Note: This graph reports the level of EY real GDP in percent deviation from a no-policy change baseline based on a four-year profile. Blue lines show simulation results from the baseline model (NGEU). Yellow (dashed-dotted) lines display simulations without an effective lower-bound (ZLB) constraint.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

Graph I.2 **Effects across countries (four-year NGEU 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 four-year 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 Member States 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).

Graph I.3 **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 Member States 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).

Table I.1 **Cross-country effects of (counterfactual) unilateral plans and NGEU**

	BE	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE
BE	0.42	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	0.00	0.02	0.00	0.01	0.01	0.01	0.00	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

Note: This table displays cross-country GDP effects after four 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 the level of 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). The last row shows the effects of the synchronised NGEU stimulus. Small differences between the column sums and the NGEU effects relate to model non-linearities. All simulations assume a four-year implementation.

Table I.2: **Cumulative (long-run and undiscounted) cross-country multipliers and spillovers**

	BE	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE
BE	5.21	0.02	0.06	0.08	1.18	0.01	0.13	0.04	0.32	1.06	0.01	0.46	0.01	0.01	0.01	0.06	0.04	0.00	0.53	0.11	0.14	0.06	0.05	0.01	0.03	0.06	0.12
BG	0.05	3.68	0.05	0.01	0.31	0.00	0.01	0.14	0.05	0.06	0.01	0.15	0.01	0.00	0.00	0.00	0.05	0.00	0.05	0.07	0.06	0.01	0.16	0.01	0.02	0.00	0.02
CZ	0.06	0.02	3.46	0.03	0.84	0.00	0.02	0.01	0.07	0.12	0.01	0.11	0.00	0.00	0.01	0.01	0.07	0.00	0.11	0.14	0.20	0.01	0.05	0.01	0.13	0.01	0.04
DK	0.04	0.00	0.02	4.88	0.35	0.01	0.03	0.01	0.03	0.06	0.00	0.03	0.00	0.01	0.01	0.01	0.01	0.00	0.10	0.02	0.07	0.01	0.01	0.00	0.01	0.05	0.26
DE	0.16	0.02	0.11	0.09	7.82	0.01	0.08	0.03	0.28	0.59	0.02	0.39	0.01	0.01	0.01	0.03	0.06	0.00	0.29	0.21	0.19	0.05	0.06	0.02	0.04	0.06	0.09
EE	0.04	0.01	0.02	0.06	0.26	2.90	0.02	0.01	0.04	0.08	0.00	0.05	0.01	0.14	0.11	0.01	0.01	0.00	0.08	0.03	0.09	0.01	0.01	0.00	0.01	0.33	0.21
IE	0.15	0.01	0.02	0.05	0.51	0.00	4.01	0.02	0.15	0.38	0.01	0.23	0.00	0.00	0.01	0.03	0.02	0.00	0.26	0.05	0.05	0.03	0.02	0.00	0.01	0.04	0.07
EL	0.05	0.04	0.01	0.03	0.30	0.00	0.03	3.14	0.10	0.18	0.01	0.18	0.03	0.00	0.00	0.01	0.01	0.00	0.07	0.04	0.02	0.02	0.03	0.01	0.01	0.02	0.02
ES	0.07	0.01	0.02	0.03	0.43	0.00	0.04	0.02	5.51	0.40	0.01	0.22	0.00	0.00	0.01	0.01	0.01	0.00	0.11	0.04	0.04	0.11	0.02	0.01	0.01	0.02	0.03
FR	0.12	0.01	0.02	0.03	0.43	0.00	0.05	0.01	0.19	4.99	0.00	0.20	0.00	0.00	0.00	0.02	0.01	0.00	0.12	0.04	0.03	0.03	0.01	0.01	0.01	0.02	0.02
HR	0.02	0.01	0.03	0.01	0.26	0.00	0.01	0.01	-0.01	-0.01	3.53	0.20	0.00	0.00	0.00	0.00	0.08	0.00	0.03	0.13	0.05	-0.00	0.02	0.13	0.02	0.00	0.01
IT	0.07	0.01	0.02	0.04	0.46	0.00	0.04	0.03	0.18	0.35	0.01	4.44	0.00	0.00	0.01	0.01	0.02	0.00	0.10	0.07	0.05	0.03	0.03	0.01	0.02	0.03	0.03
CY	0.06	0.02	0.02	0.05	0.42	0.01	0.04	0.25	0.11	0.19	0.01	0.19	3.50	0.01	0.01	0.01	0.02	0.02	0.11	0.05	0.06	0.03	0.03	0.01	0.02	0.03	0.04
LV	0.04	0.01	0.03	0.08	0.32	0.15	0.03	0.01	0.06	0.12	0.00	0.10	0.01	3.67	0.22	0.01	0.01	0.00	0.08	0.04	0.12	0.01	0.01	0.01	0.01	0.10	0.15
LT	0.07	0.01	0.04	0.09	0.46	0.09	0.03	0.01	0.14	0.20	0.01	0.15	0.00	0.18	3.73	0.01	0.02	0.00	0.12	0.06	0.23	0.02	0.01	0.01	0.02	0.08	0.14
LU	0.25	0.01	0.02	0.04	0.72	0.00	0.10	0.01	0.18	0.59	0.00	0.39	0.00	0.00	0.00	2.13	0.02	0.00	0.18	0.06	0.06	0.03	0.02	0.01	0.01	0.03	0.08
HU	0.06	0.02	0.11	0.03	0.74	0.00	0.02	0.01	0.06	0.10	0.04	0.13	0.00	0.00	0.01	0.01	3.41	0.00	0.10	0.18	0.14	0.01	0.13	0.03	0.10	0.01	0.04
MT	0.05	0.02	0.02	0.07	0.54	0.01	0.06	0.07	0.15	0.31	0.02	0.28	0.03	0.00	0.01	0.02	0.01	2.86	0.13	0.07	0.05	0.03	0.02	0.01	0.01	0.03	0.09
NL	0.24	0.01	0.05	0.07	0.91	0.01	0.14	0.02	0.19	0.45	0.01	0.24	0.00	0.01	0.01	0.02	0.03	0.00	3.75	0.08	0.09	0.04	0.03	0.01	0.02	0.05	0.09
AT	0.10	0.02	0.11	0.05	1.30	0.01	0.05	0.03	0.16	0.33	0.03	0.35	0.00	0.01	0.01	0.02	0.09	0.00	0.17	5.31	0.13	0.03	0.07	0.04	0.08	0.04	0.06
PL	0.05	0.01	0.09	0.04	0.57	0.01	0.02	0.01	0.05	0.12	0.01	0.10	0.00	0.01	0.02	0.01	0.04	0.00	0.09	0.06	3.76	0.01	0.04	0.01	0.04	0.02	0.06
PT	0.08	0.01	0.02	0.03	0.46	0.00	0.05	0.01	0.62	0.42	0.01	0.20	0.00	0.00	0.01	0.01	0.01	0.00	0.12	0.04	0.03	4.58	0.02	0.01	0.01	0.03	0.03
RO	0.04	0.04	0.04	0.01	0.36	0.00	0.01	0.02	0.07	0.13	0.01	0.19	0.00	0.00	0.00	0.01	0.06	0.00	0.06	0.07	0.07	0.01	3.48	0.01	0.03	0.01	0.02
SI	0.06	0.02	0.07	0.04	0.68	0.00	0.03	0.03	0.11	0.25	0.16	0.43	0.00	0.00	0.01	0.01	0.09	0.00	0.09	0.26	0.11	0.02	0.06	2.96	0.05	0.02	0.04
SK	0.07	0.02	0.29	0.03	0.80	0.00	0.03	0.01	0.11	0.26	0.02	0.21	0.00	0.01	0.01	0.01	0.14	0.00	0.11	0.22	0.22	0.02	0.07	0.03	3.23	0.02	0.04
FI	0.06	0.01	0.02	0.07	0.42	0.05	0.04	0.01	0.08	0.17	0.00	0.11	0.00	0.01	0.02	0.01	0.01	0.00	0.13	0.04	0.05	0.02	0.01	0.00	0.01	4.61	0.25
SE	0.05	0.00	0.02	0.16	0.22	0.02	0.03	0.00	0.01	0.04	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.10	0.02	0.07	0.00	0.01	0.00	0.01	0.15	4.65

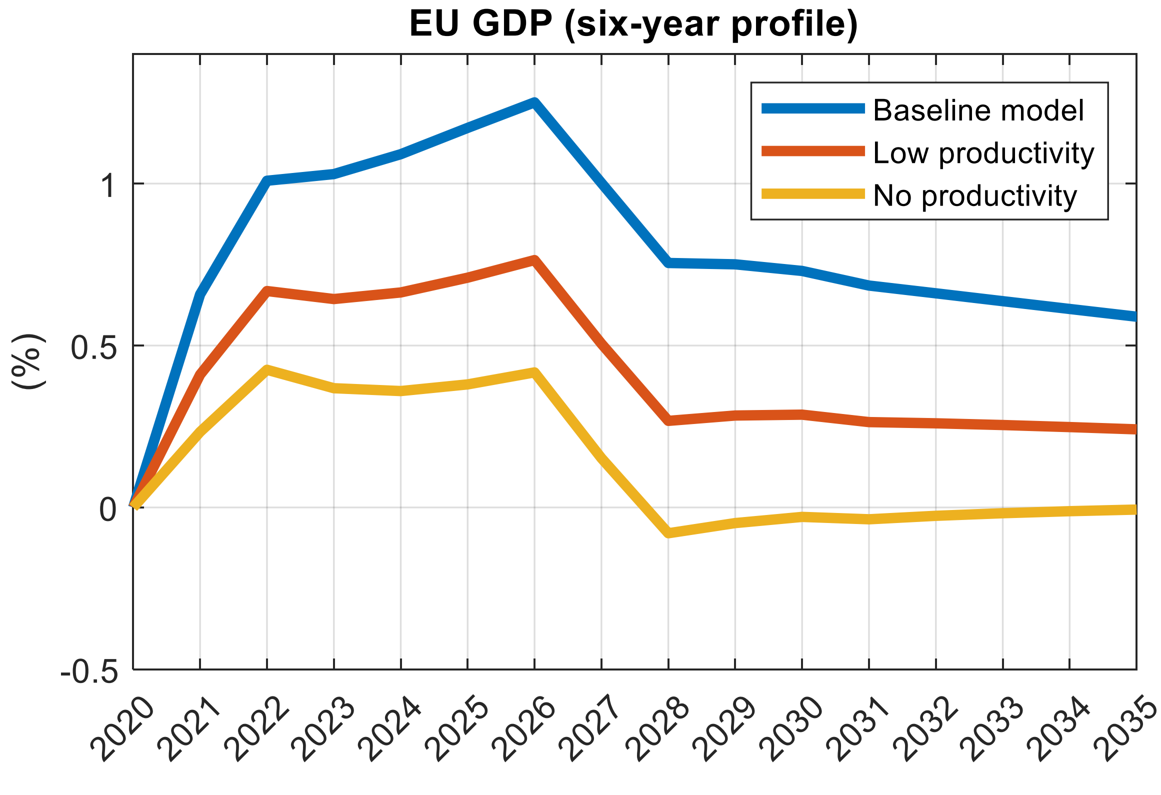
Note: This table displays cross-country (cumulative) long-run output multiplier and spillover of the counterfactual unilateral investment plans (by row) on the other countries (by column). We normalize the multiplier by the NGEU investment in the country of origin. For example, the cell in row DE and column BE shows that the each unit unilateral German stimulus plan increase Belgian GDP by 0.16 units, 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). All simulations assume a six-year implementation.

I.2 SENSITIVITY: THE ZERO PRODUCTIVITY CASE

This section illustrates the importance of productive public capital. We consider three scenarios: (i) Our baseline calibration targets the empirical median estimate, which suggests an output elasticity of public capital, denoted α^G, of around 0.12.[12] (ii) Our low-productivity calibration uses $\alpha^G = 0.05$ – around the values used in Baxter and King (1993) and Leeper (2010). (iii) The extreme fully unproductive case ("bridges to nowhere") sets $\alpha^G = 0$.

The simulation results in Figure I.4 underline the importance of "high-quality" government investment. The effects range from a peak of around 1.3% of GDP to negligible medium-run effects - crucially depending on the assumed output elasticity. For productive investment, the level of real GDP remains high even when the government discontinues its investment after six years. While sizeable growth effects remain even under more pessimistic assumptions (except in the case of unproductive spending), the changes across assumptions are pronounced. As expected, there are no long-run gains from the public-investment stimulus under zero productivity.

Graph I.4 **Sensitivity and assumptions on the output elasticity of public capital.**



Note: This graph reports the level of real EU GDP in per cent deviation from a no-policy change baseline. Model simulations use different calibration of the output elasticity of public capital, i.e. 0.12 (blue), 0.05 (red) and 0 (yellow). The horizontal axis is in years. All results refer to a six-year scenario.

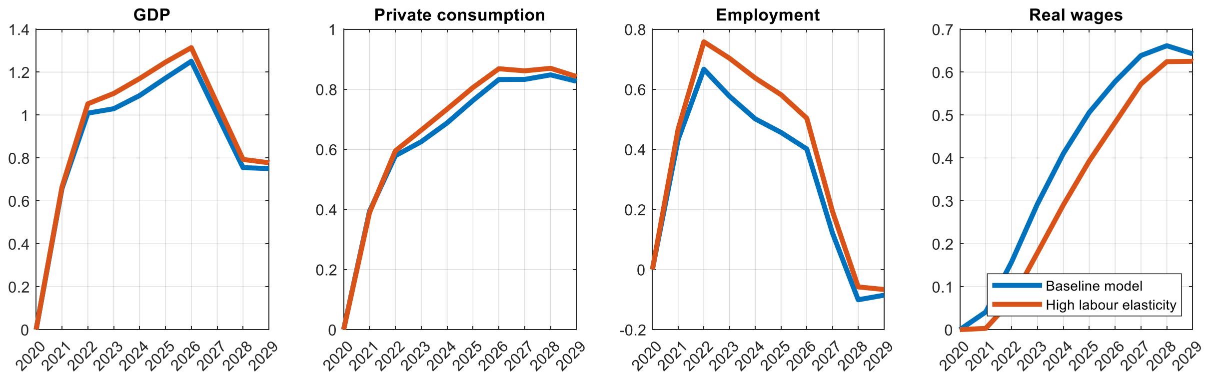
[12] Bom and Ligthart, J. (2014).

I.3 SENSITIVITY: LABOUR SUPPLY ELASTICITY

This section studies the role of labour supply elasticity. Our baseline calibration broadly follows Chetty et al (2011) and Chetty (2012) and sets $1/\kappa = 0.2$. Graph I.5 presents a robustness check, setting the Frisch elasticity to 0.5. A higher Frisch value may, e.g., result from rising female labour force participation.

The results under the higher Frisch elasticity are qualitatively the same as under the benchmark value. However, there are moderate quantitative differences. In particular, increasing the Frisch elasticity increases the positive employment, consumption, and output effects following the investment stimulus. At the same time, a larger elasticity also dampens the real wage response.

Graph I.5 **Sensitivity higher labour supply elasticity**

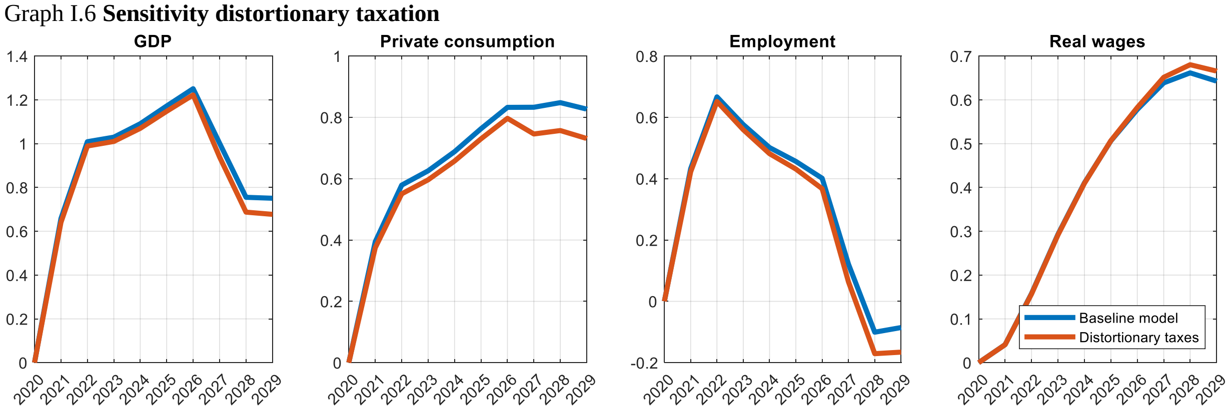


Note: This graph reports all variables in per cent deviation from a no-policy change baseline. Model simulations use different calibration of the Frisch elasticity, i.e. 0.2 (blue), 0.5 (red). The horizontal axis is in years. All results refer to a six-year scenario under high productivity.

I.4 SENSITIVITY: DISTORTIONARY TAXATION

Our main simulations assume that domestic lump-sum taxes finance the NGEU contributions. Instead, this section considers that the national governments raise these contributions via distortionary labour taxes (starting in 2027 as in the main simulations).

Graph I.6 **Sensitivity distortionary taxation**



Note: This graph reports all variables in per cent deviation from a no-policy change baseline. Model simulations consider lump-sum taxes (blue) and distortionary labour taxes (red). The horizontal axis is in years. All results refer to a six-year scenario under high productivity.

As shown in Graph I.6, the results are quantitatively close to our main results. However, as expected, distortionary labour taxes reduce the positive employment impact. Consumption and output effects also increase less, notably after 2027, when, according to our assumptions, the national governments start to raise the NGEU contributions.

REFERENCES (APPENDIX)

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