

Annexes

1. Annex to Chapter 1

Online annexes to [Chapter 1](#) of the Euro Area Stability Watch present the data sources, analytical frameworks, and methodologies supporting the chapter's risk assessment. They are organised in line with the chapter structure, covering the technical underpinnings of the boxes, the design of the adverse macroeconomic and fiscal scenarios, and key indicators, alongside additional analyses and robustness checks.

A1 Data and methodological supplement to Box 1.1

This annex provides details on the methodology underlying the analysis presented in [Box 1.1](#). A large language model extracts structured, market-relevant news indicators from daily expert commentary, which then feed into a factor-augmented event study regression to quantify how different types of news move financial variables.

A1.1 Large language model-based extraction of news dummies

Text data source and news extraction pipeline

The text corpus for our analysis is a daily commentary available since September 2018 and produced by experts from the International Monetary Fund's Monetary and Capital Markets Department (the Global Markets Monitor). The large language model analyses each report in the sample and extracts a small set of news items, which were reported as relevant for equity and government bond price movements, respectively. Specifically, each day's Global Markets Monitor report is parsed by the model with a prompt that instructs it to identify the distinct market-moving news and events discussed in the commentary and assign each item to one of 15 pre-defined, economically interpretable categories following Baker et al. (2025). In a second step, for our regression analysis, we further aggregate the original classifications of Baker et al. (2025) into five headline categories as follows (original categories in brackets):

1. Global markets (commodities, foreign markets)
2. Macroeconomy (macroeconomic news and outlook, corporate earnings and outlook, other non-policy)
3. Monetary policy
4. Fiscal and structural policy (government spending, taxes, exchange rate policy, capital controls, international trade policy, regulation, elections and political transitions, other policy)

5. Conflicts and security (sovereign military and security actions, terrorist attacks and large-scale violence by non-state actors)

From news items to daily news dummies

For each category, the large language model analysis generates two daily 'news dummies' (one for risk-free yields and one for equities) that take the value of 1 if the commentary for day t contains at least one event of the category that is associated with movements in bond or equity prices. The two resulting sparse matrices of category-by-day dummies then feed into the factor-augmented event study regression (denoted d_1^{news} and d_2^{news} in the equation below).

A1.2 Factor-augmented event-study model with latent news factors

Data

We combine daily financial-market data with macroeconomic release surprises, monetary policy surprises, and the news measures outlined in [Section A1.1](#). Euro area risk-free yields are proxied by the German yield curve: the first and fourth Euribor futures and 2-, 5-, 10-, and 30-year Bund futures (Gürkaynak et al., 2022). Other variables include the EUROSTOXX 50, the VSTOXX index, aggregate corporate spreads (AAA, BBB, high-yield), and the euro area TED spread (3-month EURIBOR minus 3-month Bund yield). Since euro area macroeconomic data surprises are conceptually largely unavailable due to earlier country-specific releases and known country weights, we use 13 important indicators for the German economy, where surprises are defined as the released value minus the median expectation of survey participants. The data were obtained from Bloomberg. Monetary policy surprises comprise the monetary policy and central bank information components for the European Central Bank and the Federal Reserve (Jarocinski and Karadi, 2020), with the latter being shifted by one day ($t+1$) to account for time zone differences.

Econometric model

The decompositions shown in [Box 1.1](#) are based on the following specification. The model is motivated by [Gürkaynak et al. \(2020\)](#), extending their analysis in terms of both dependent and explanatory variables. Our specification decomposes (de-measured) daily changes in the yields of (risk-free) government bonds at different maturities (r_t with dimension $N_1 \times 1$) and the other market-based (risk) measures (σ_t with dimension $N_2 \times 1$) as follows:

$$\begin{bmatrix} r_t \\ \sigma_t \end{bmatrix} = \begin{bmatrix} \beta^r \\ \beta^\sigma \end{bmatrix} s_t + \begin{bmatrix} \gamma^r \\ \gamma^\sigma \end{bmatrix} d_t^s f_{1,t} + \begin{bmatrix} \delta_1^r \\ \delta_1^\sigma \end{bmatrix} (d_{1,t}^{news} \odot f_{2,t}) + \begin{bmatrix} \mathbf{0} \\ \delta_2^\sigma \end{bmatrix} (d_{2,t}^{news} \odot f_{3,t}) + \varepsilon_t$$

$$f_{1,t} \sim N(0, 1), \quad f_{2,t} \sim N(\mathbf{0}, I_{K_2}), \quad f_{3,t} \sim N(\mathbf{0}, I_{K_2}), \quad \varepsilon_t \sim N(\mathbf{0}, \Sigma)$$

with $t = 1, \dots, T$, $i = 1, \dots, N$, $N = N_1 + N_2$, and where s_t is a $(K_1 \times 1)$ vector of observed data release surprises, d_t^s is a dummy vector for release days (one if any of the indicators in s was published on day t), and $d_{1,t}^{news}$ and $d_{2,t}^{news}$ are $(K_2 \times 1)$ dummy matrices for bond and equity market-relevant news, respectively. The unobserved data release factor $f_{1,t}$ and the $(K_2 \times 1)$ unobserved news factors $f_{2,t}$ and $f_{3,t}$ are assumed normally distributed with unit variance to identify their scales. The flexible two-factor structure for the news components is motivated by recent analyses suggesting that aggregate financial conditions can be characterised by two distinct factors, one capturing dynamics in risk-free yields and the other capturing financial risk ([Lombardi et al., 2025](#)). β^r , β^σ , γ^r , γ^σ , $\delta_1^r, \delta_1^\sigma$, and δ_2^σ are coefficient matrices of corresponding dimensions. Lastly, ε_t is the error term, with diagonal covariance matrix Σ . The model is estimated with a Bayesian approach (Gibbs sampling), using relatively uninformative prior distributions. The contribution of data surprises shown in the charts includes both observed and unobserved data release surprises, with the latter being captured through f_1 . Finally, the contributions of the news categories for the non-yield variables reflect the combined impact of f_2 and f_3 .

A1.3 References

Baker, S. R., N. Bloom, S. J. Davis, and M. Sammon. What triggers stock market jumps?, mimeo, 2025.

Gürkaynak, R. S., B. Kisacikoglu, and J. H. Wright. Missing events in event studies: Identifying the effects of partially measured news surprises, *American Economic Review*, 110(12):3871–3912, 2020.

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A2 Data and methodological supplement to Box 1.2

This annex provides details on the methodology underlying the analysis presented in [Box 1.2](#). It outlines the data and empirical framework used to estimate the effects of geopolitical risk and financial uncertainty shocks on foreign investor inflows into euro area and United States (US) government debt securities from January 1999 to December 2024.

A2.1 Shocks

We use the global geopolitical risk (GPR) index of Caldara and Iacoviello (2022) as our main measure of adverse geopolitical episodes. The index is constructed as the share of newspaper articles containing GPR-related keywords in major Anglo-American newspapers, relative to the total number of published articles. It provides a high-frequency, text-based measure of global geopolitical tensions.

In addition, we include the VIX index (a measure of US stock market volatility) to proxy for global financial market uncertainty. While related, GPR and financial uncertainty are conceptually different. The former reflects geopolitical events and tensions, whereas the latter captures broader market volatility and risk sentiment. Caldara and Iacoviello (2022) show that the GPR index displays substantial independent variation relative to both the VIX and the news-based Economic Policy Uncertainty index of Baker, Bloom, and Davis (2016). This allows us to study these two distinct sources of shocks separately.

All shock variables are standardised to have zero mean and unit variance. Therefore, the estimated coefficients can be interpreted as the response to a one standard deviation shock. To allow for nonlinear effects, we further define high-risk periods as observations in which the shock exceeds its 90th percentile.

A2.2 Monthly portfolio debt liability flows into government securities

Data on non-euro area investors' net purchases of euro area government securities are sourced from the European Central Bank (ECB) balance of payments statistics dataset and are available at monthly frequency from 2008. Data coverage includes both short- and long-term instruments. To ensure comparability with the US analysis, euro area flows are extended back to 1999. For the 1999–2007 period, flows are constructed by aggregating non-resident net purchases for euro area countries with available data, using ECB balance of payment statistics and national central bank sources. These imputed flows before 2008 include transactions by investors resident in other euro area countries. Results based solely on reported ECB balance of payment statistics from 2008 onward are qualitatively similar, and including intra-euro area flows does not materially affect the findings over the common sample period 2008–2024.

Monthly data on foreign investors' net purchases of US government securities are sourced from the Treasury International Capital (TIC) system. As recommended by Bertaut and Judson (2025), reported TIC data are used from 2023 onward, while earlier flows are based on valuation-adjusted estimates from Bertaut and Tryon (2007) and Bertaut and Judson (2014, 2022), using information from the TIC Survey of Long-Term Securities. US government securities include both Treasury and agency securities. Long-term instruments (above one year) are drawn from the valuation-adjusted datasets, while short-term instruments are directly sourced from TIC data. Compared with the euro area data, the US data provide greater granularity along both the counterpart-sector and counterpart-country dimensions. This enables distinguishing between foreign official investors (primarily foreign central banks) and foreign private investors, and, within the latter group, between investors resident inside and outside the euro area.

Flow data are scaled by one-year-lagged annual gross domestic product (GDP). The analysis relies on monthly flow data without any further transformation. A local projection specification, discussed in detail below, is then used to estimate cumulative flow responses to shocks. Results are robust to using three-month moving averages, which yields smoother impulse responses.

A2.3 Local projections framework

Our empirical strategy examines how foreign investors' flows into government securities respond to GPR and financial-market uncertainty shocks using monthly local projections in the style of Jordá (2005). The analysis is conducted separately for the US and the euro area. For each forecast horizon $h=0, 1, 2, \dots, 12$, we estimate:

$$\sum_{j=0}^h y_{t+j} = \alpha^{(h)} + \beta_1^{(h)} shock_t + \beta_2^{(h)} (shock_t \times 1(shock_t > q_{0.9})) + \beta_3^{(h)} (1(shock_t > q_{0.9})) + \sum_{s=1}^p \delta_s^{(h)} (y_{t-s}) + \sum_{s=1}^k \gamma_s^{(h)} Z_{t-s} + \varepsilon_{t+h}$$

The dependent variable y is monthly portfolio liability flows into government debt securities, expressed as a share of annual GDP in period $t-12$ (same scaling for each h). The variable $shock$ corresponds to either GPR or financial-market volatility (measured by the VIX), both standardised. To capture nonlinear effects, we interact the shock with an indicator for high-risk periods, defined as observations above the 90th percentile of the shock distribution.

The vector Z includes a set of lagged control variables (including lags of the shock) capturing global financial conditions and macro-financial characteristics, considered as

push and pull factors of capital flows, respectively. The specification differs slightly between the euro area and the US to reflect relevant market structures. For euro area (US) specifications, the baseline controls include VIX, the STOXX 600 index (S&P 500 index), Brent oil prices (WTI oil prices), the US NFCI, and 3-month EURIBOR (3-month US government yields). All controls, except the VIX, are expressed in first differences to address non-stationarity. While all control variables are included with two lags, the dependent variable is included with up to 12 lags to account for persistence in capital flows; results are robust to alternative lag lengths of two and six.

The impulse response functions are constructed from the sequence of estimated coefficients $\left\{ \beta_1^{(h)} \right\}_{h=0}^H$, which tracks the dynamic cumulative response of capital flows to shocks during normal periods. Specifically, the additional effect during high-risk episodes is captured by the sequence $\left\{ \beta_2^{(h)} \right\}_{h=0}^H$, which measures how the cumulative response of capital flows differs when shocks occur in periods of heightened geopolitical or financial stress.

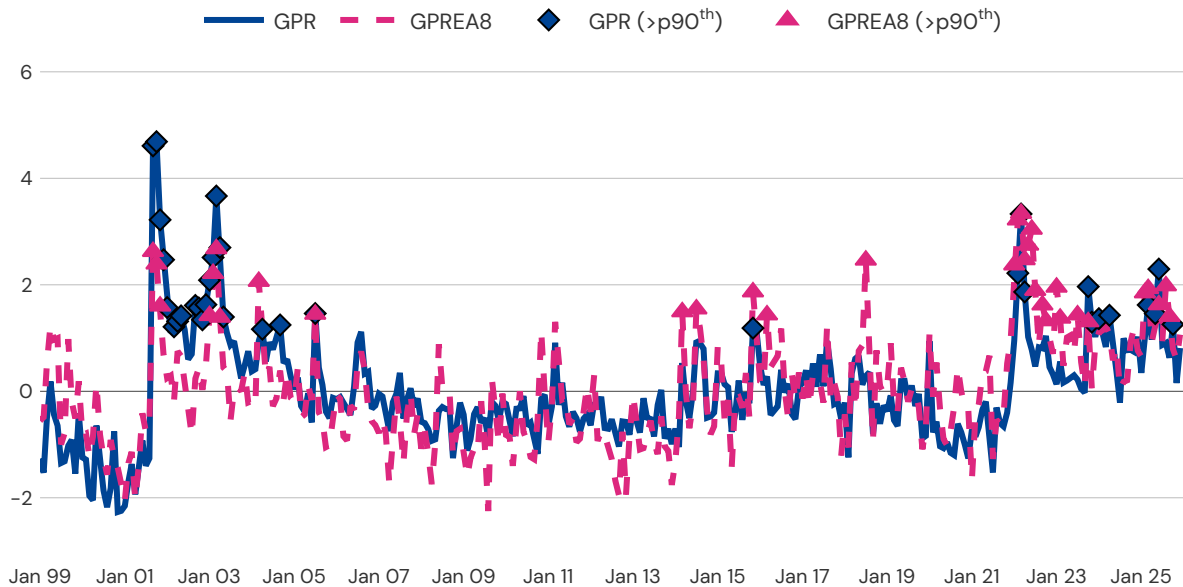
A2.4 Supplementary results

We also employ a euro area-specific geopolitical risk measure (hereafter GPREA8) designed to capture episodes in which geopolitical tensions are directly centred on the euro area. Caldara and Iacoviello (2022) provide country-specific GPR indices based on articles combining geopolitical-risk keywords with country identifiers; we construct GPREA8 as the simple average of eight euro area country indices. It complements the global GPR index by isolating regionally relevant geopolitical shocks that may have different implications for capital flows given differences in geographical proximity and exposure to geopolitical events. As illustrated in [Figure A2.1](#), GPR and GPREA8 do not always peak in the same periods; and even when their peaks coincide, they often differ in intensity, reflecting differences in the underlying events they capture.

Figure A2.1

Standardised GPR and GPREA8 indices

(January 1999 to December 2025)



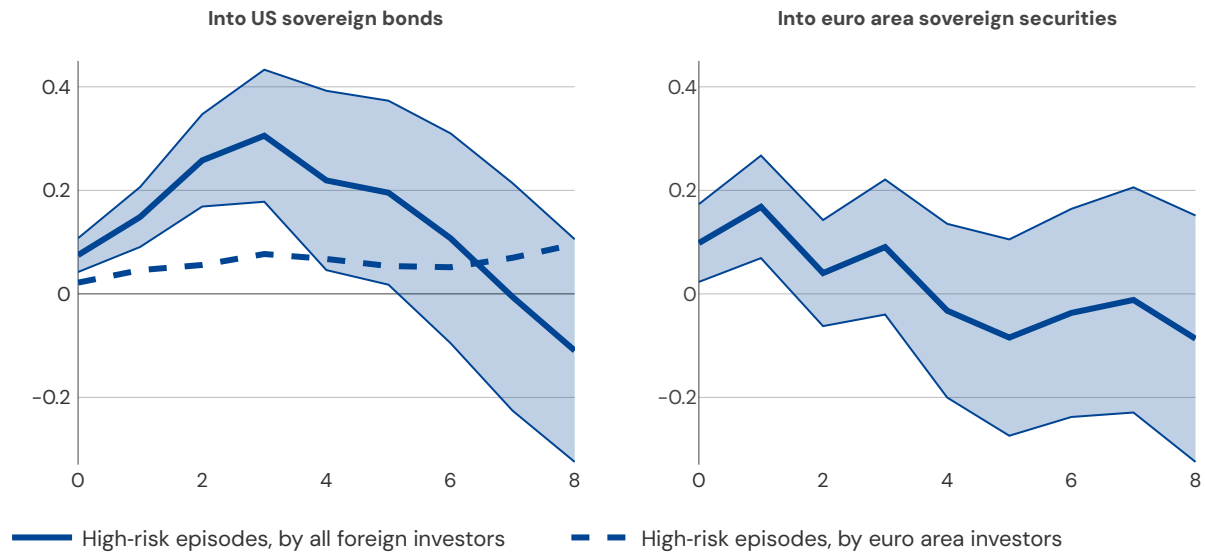
Note: Standardised GPR and GPREA8 indices, together with the months in which each index exceeds its 90th percentile.

Source: ESM calculations based on Caldara and Iacoviello (2022) data

Interestingly, when extreme geopolitical tensions are closely linked to the euro area, foreign demand for US sovereigns reasserts itself. Using GPREA8, results show that periods of elevated geopolitical tensions centred on the euro area (such as the Russian invasion of Ukraine), prompt short-lived inflows into US Treasuries from foreign investors, including those of the euro area, peaking after a quarter (Figure A2.2). At the same time, foreign demand for euro area sovereign debt remains resilient, with no evidence of reversal and, if anything, a mildly positive response in the aftermath of such shocks. This reinforces our main finding that euro area sovereign debt remains resilient even during episodes of high geopolitical stress concentrated within the region.

Figure A2.2

Flows into government bonds after euro area-specific GPR shocks



Notes: Cumulative impulse responses following a one standard deviation shock in the euro area GPR (GPREA8), in months when GPREA8 > 90th percentile. Shaded areas: 68% confidence intervals.
Source: ESM calculations

A2.5 References

Caldara, D. and M. Iacoviello (2022). Measuring geopolitical risk. *American Economic Review*, 112(4), 1194–1225.

Baker, S. R., N. Bloom, and S.J. Davis (2016). Measuring economic policy uncertainty. *Quarterly Journal of Economics*, 131(4), 1593–1636.

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Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1), 161–182.

A3 Data and methodological supplement to Box 1.3

This annex provides details on the data and empirical approach used to estimate the effects of the ‘new geopolitical regime’ (since the outbreak of the Russia-Ukraine war) on banks’ lending dynamics, conditional on the level of banks’ sovereign exposures.

A3.1 Data

The dataset is an unbalanced panel of 82 banks from 18 euro area countries that spans between Q4 2019 and Q4 2025 at quarterly frequency. Data come from the Transparency Exercise of the European Banking Authority and are merged with macro-financial variables.

A3.2 Methodology

To estimate the effect of the ‘new regime’ on bank lending – conditional on banks’ sovereign exposures – we employ the local projections method (Jordà, 2005) and estimate the following regression:

$$\begin{aligned} \ln(\text{Loans}_{b,t+h}) - \ln(\text{Loans}_{b,t-1}) = & \alpha + \beta_{1,h} \text{ new regime} + \\ & \beta_{2,h} \text{ sovereign exposures} / \text{TA}_{b,t-1} \\ & + \beta_{3,h} \text{ new regime} \times \text{sovereign exposures} / \text{TA}_{b,t-1} + \beta_{4,h} \text{ Controls}_{b,t-1} + \delta_{b,h} + \\ & \varepsilon_{b,t+h} \end{aligned}$$

Here, $\ln(\text{Loans}_{b,t+h}) - \ln(\text{Loans}_{b,t-1})$ is the log difference of loans of bank b between quarter $t-1$ and $t+h$, with $h = 0, 1, \dots, 8$. Specifically, we consider loans to energy-intensive sectors (mining, manufacturing, transport, and water supply) and loans to non-energy-intensive sectors as identified by the European Systemic Risk Board (2026).

represents a dummy that assumes the value of 1 from Q2 2022 onwards, corresponding to the quarter after the start of the Russia-Ukraine war, and 0 otherwise. $\text{Sovereign exposures} / \text{TA}_{b,t-1}$ captures the share of each bank's sovereign exposures (loans and bonds) over total assets. The key term of interest is $\beta_{3,h}$ (i.e. the interaction $\text{new regime} \times \text{sovereign exposures} / \text{TA}_{b,t-1}$), which measures the differential effect of sovereign exposures on bank lending between the ‘old regime’ and the ‘new regime’.

Controls $_{b,t-1}$ is a vector of lagged financial sector and macroeconomic controls. It includes a Covid-19 dummy (dummy=1 for 2020), CET1 ratio (capital position of bank), stage 2 ratio (loans classified as stage 2 over total loans), return on assets, cash ratio (cash over assets), non-bank financial institution asset growth (quarter-on-quarter growth in assets of the non-bank financial institution sector), quarter-on-quarter gross domestic product growth, quarter-on-quarter changes in Euribor, government debt growth (quarter-on-quarter growth rate of government debt) and European Central Bank asset growth (quarter-on-quarter growth of bank's balance sheet). $\delta_{b,h}$ is bank fixed effects and $\varepsilon_{b,t+h}$ the error term. Standard errors are clustered at the bank level.

A3.3 References

European Systemic Risk Board (2026), Financial stability risks from geoeconomic fragmentation, January 2026.

Jordà, Ò. (2005), Estimation and Inference of Impulse Responses by Local Projections, American Economic Review, 95(1), 161–182.

A4 Data and methodological supplement to Box 1.4

This annex provides details on the data and implementation of the granular instrumental variables (GIV) estimation used to determine the impact of aggregate investor demand shocks on sovereign yield spreads presented in [Box 1.4](#).

A4.1 Granular instrumental variables

While derivations and discussions are provided in Gabaix and Koijen (2021, 2022, 2024), the GIV approach requires modelling choices specific to the application at hand. Refinements to the GIV method create a range of possibilities for construction of the instruments. Specific choices for the results presented in [Box 1.4](#) are outlined below.

Isolating the causal relationship between bond flows and yield movements is challenging due to the endogeneity of bond supply and demand. Within a demand system-based asset pricing framework, the GIV approach addresses this issue by constructing an exogenous instrument Z_t from a weighted sum of idiosyncratic shocks $u_{i,t}$ to different investor groups. Because these shocks $u_{i,t}$ are exogenous investor-specific flows, they are orthogonal to common macroeconomic factors and aggregate market movements, while remaining correlated with the yields. Thus, considering N different investor groups with time-varying market shares $S_{i,t}$, the GIV instrument is defined as:

$$z_t = \sum_{i=1}^N S_{i,t-1} u_{i,t}$$

Given the instrument z_t , the price impact captured via the change in the spreads Δs_t (vis-à-vis German Bunds) can then consistently be estimated using the regression:

$$\Delta s_t = c + Mz_t + \lambda' \eta_t + \varepsilon_t$$

where M denotes the impact on the spreads, z_t is the GIV instrument, and η_t denotes a vector of observed and latent common factors $\eta_t = (\eta_t^o, \eta_t^l)$, such as macroeconomic conditions or global uncertainty. However, as investor-specific shocks $u_{i,t}$ and latent controls η_t^l are unobserved, they need to be estimated from data to construct the instrument.

To take heterogeneity across different investor groups into account, we use precision weights:

$$E_i = \frac{\bar{\sigma}_{u_i}^{-2}}{\sum_{i=1, \dots, N} \bar{\sigma}_{u_i}^{-2}}$$

where $\bar{\sigma}_{u_i} = \max(\sigma_{u_i}, \text{median}(\sigma_{u_i}))$ and σ_{u_i} is the standard deviation of $u_{i,t}$ computed along the time dimension¹. The algorithm cycles through three steps²:

1. Estimate weighted panel regression including observed controls and fixed effects using E_i as regression weights to obtain first stage residuals $\Delta \check{q}_{i,t}$:

$$\Delta q_{i,t} = \alpha_i + \gamma' \eta_t^o + \Delta \check{q}_{i,t}$$

2. Perform principal component analysis on precision-weighted residuals $E_i^{\frac{1}{2}} \Delta \check{q}_{i,t}$ to recover latent factors η_t^l given by the principal components.
3. Run ordinary least squares regression of common factors η_t^l on first stage residuals $\Delta \check{q}_{i,t}$: to estimate investor-specific shocks $\check{u}_{i,t}$ and update precision weights $\bar{\sigma}_{u_i}$, and iterate again, where:

$$\Delta \check{q}_{i,t} = \beta' \eta_t^l + \check{u}_{i,t}$$

Once we have obtained estimates $\check{u}_{ji,t}$ for each country, we construct the GIV instrument as:

$$z_{j,t} = \sum_{i=1}^N S_{ji,t-1} \hat{u}_{ji,t}$$

and collect the recovered latent factors η_t^l as controls in the main regression. Once the instruments are obtained for each country in a group, the impact effect is estimated running the group-specific panel regression

$$\Delta s_t = c + M z_{j,t} + \lambda' \eta_t + \varepsilon_t$$

using the observed and recovered unobserved factors for each country group as controls.

Similarly, we estimate the panel local projections for each country group as follows:

$$s_{t+h} - s_{t-1} = c_h + M_h z_{j,t} + \lambda'_h \eta_t + \varepsilon_{t+h}$$

We specify three iterations as no significant changes of the precision weights are apparent, suggesting convergence of the algorithm. The regression includes the same set of observed factors to η_t^0 as Chaudhary et al. (2025) and one additional latent factor η_t^l obtained from the principal component analysis in step 2.

A4.2 Data

Price sensitivities are measured using 10-year sovereign yields, obtained from Bloomberg, consistent with an average residual maturity of around 7.5 years over the sample period.

The estimation is based on quarterly data on investor shares and flows. The sample spans Q4 2014–Q4 2025 and compiles estimates of investor holdings at market value, together with quarterly transactions in debt securities issued by the general government. The data are compiled from several sources, including the European Central Bank (ECB)'s quarterly sector accounts (QSA), securities holdings statistics (SHS), and securities holdings statistics by sector (SHSS), data on the Eurosystem's asset purchase programmes, the International Monetary Fund's International Financial Statistics and Eurostat's balance of payments statistics.

Data compilation inevitably relies on assumptions. Notably, non-euro area holdings are computed as a residual, while investor flows (net purchases) prior to 2021 – when ECB SHSS data become available – are inferred from valuation-adjusted changes in holdings. Hence, any measurement limitations affecting euro area investor coverage and valuation adjustments are reflected in the residual non-euro area category.

Specifically, the primary data source is the ECB's QSA which reports, for each country, government debt securities holdings and net transactions for all investors, including a breakdown of domestic investors by sector and a single aggregate category for non-resident investors. For several countries, data on domestic central bank holdings are missing for some periods; coverage is therefore extended using the International Monetary Fund's International Financial Statistics series on gross claims of monetary authorities on general government at market value.

A second key source is the ECB's SHSS, which provides, for each country, a sectoral breakdown of holdings and transactions for euro area investors. SHSS data are available from Q1 2021. Coverage is extended back to 2014 using the discontinued SHS dataset, which reports holdings at market value but not flows. Flows are therefore approximated using changes in holdings, adjusted for valuation effects. Investor-specific valuation changes are computed using QSA data for domestic investors, assuming that valuation effects are comparable across domestic and other euro area investors. As the SHS dataset does not provide a series for Eurosystem holdings, the SHSS coverage is extended using constructed series on stocks and flows implied by asset purchase programmes (securities markets programme, public sector purchase programme, and pandemic emergency purchase programme).

Overall, total holdings are taken from QSA data, with domestic and sectoral breakdowns based on QSA, euro area investor breakdowns based on SHSS, and non-euro area holdings calculated as a residual.

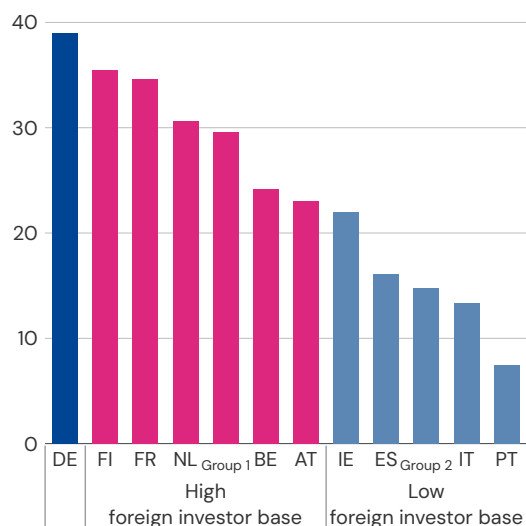
For the analysis, euro area countries are classified into two groups based on their latest share of non-euro area investors, distinguishing five countries with relatively high non-euro area investor shares and four countries with a more euro area-dominated investor base (Figure A4.1, panel a). Over the sample period, non-euro area investor shares average around 31% in the first group and 14% in the second. As regards euro area investors, insurance corporations and pension funds are also more prominent in the first group, whereas the Eurosystem, banks and households account for larger shares in the second group (Figure A4.1, panel b).

Figure A4.1

A heterogeneous investor base

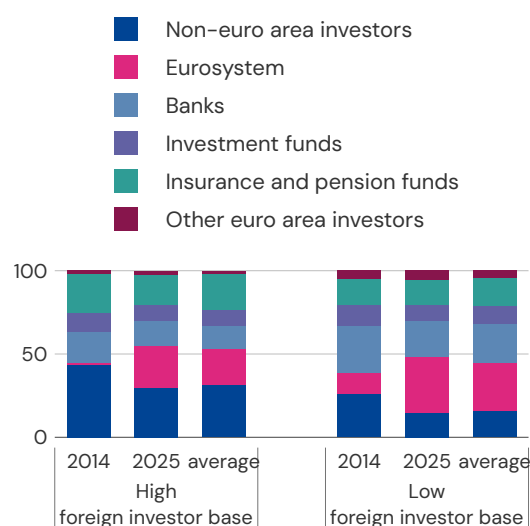
a) Non-euro area investor share by country, Q4 2025

(sector market shares, in % of total government debt securities)



b) Sectoral holdings shares across the two groups of countries

(sector market shares, in % of total government debt securities)



Notes: Panel a) shows estimates of the share of euro area government debt securities held by non-euro area investors, by country, as of end-2025. Panel b) presents the sectoral composition of the investor base for two groups of countries, constructed based on their non-euro area investor shares. The sample comprises nine euro area countries for which data are available prior to the start of the ECB's quantitative easing: Austria, Belgium, Finland, France, Ireland, Italy, Netherlands, Portugal, and Spain. Germany is not part of either group, as the estimation relies on spreads relative to German Bunds.

Source: ESM calculations based on ECB, Eurostat, and International Monetary Fund data

A4.3 References

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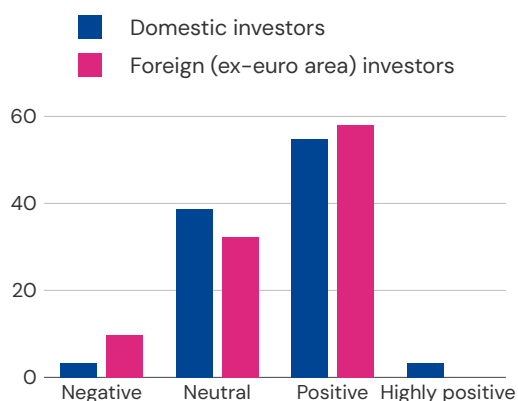
A5 Data and methodological supplement to Box 1.5

Results of the ESM Sovereign Sentiment Survey are based on a survey of 31 financial market participants active in euro area sovereign bond markets, conducted between 27 March and 17 April 2026. The sample includes issuers (debt management offices and treasuries), intermediaries, and investors. Sample euro area growth (1.0% median, 1.1% average) and euro area inflation (2.9% average, 3.0% median) expectations over the next 12 months are in line with market consensus; recession probability for the euro area (30% average, 33% median) is above consensus. In addition to the survey, structured interviews were conducted with 18 market participants in April 2026. The survey will be repeated twice a year from now on (Q2 and Q4).

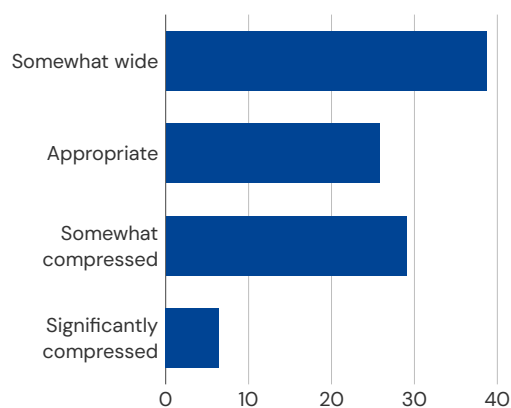
Figure A5.1

Sentiment towards euro area sovereign bonds

- a) Sentiment towards euro area sovereign bonds
(share of respondents, in %)



- b) Views on euro area sovereign bond spread levels
(share of respondents, in %)



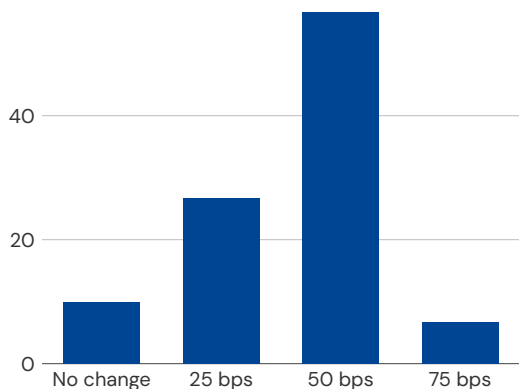
Note: Spreads between 10-year euro area sovereign bonds and 10-year German sovereign bonds.

Source: ESM Sovereign Sentiment Survey, Q2 2026

Figure A5.2

Euro area interest rates expectations

a) European Central Bank policy rate expectations
(basis point change exp. over 12 months)



Note: "bps" stands for basis points.

Source: ESM Sovereign Sentiment Survey, Q2 2026

b) 10-year Bund yield level expected in 12 months
(share of respondents, in %)

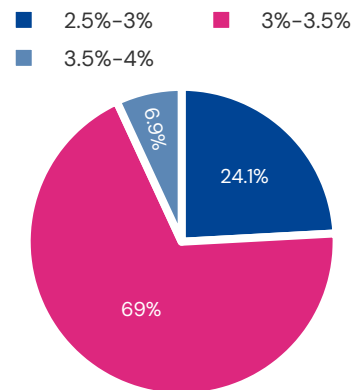
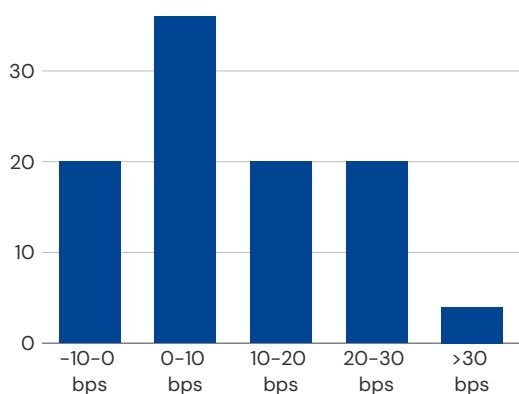


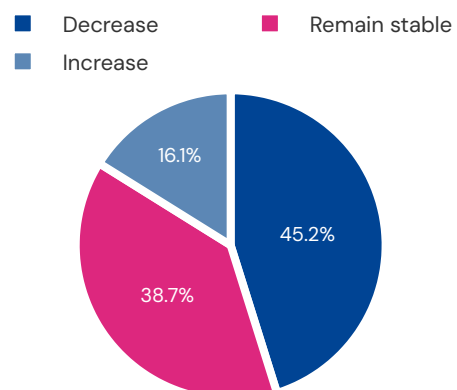
Figure A5.3

Swap spread and maturity expectations

a) EUR swap spread level expected in 12 months
(share of respondents, in %)



b) Average maturity of euro area sovereign issuance over 12 months
(share of respondents, in %)



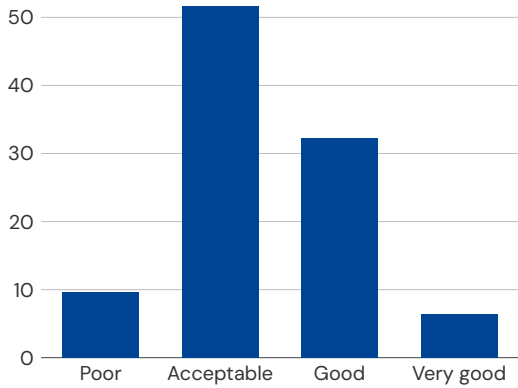
Notes: Swap spread defined as EUR swap rate less German bond yield. "bps" stands for basis points.

Source: ESM Sovereign Sentiment Survey, Q2 2026

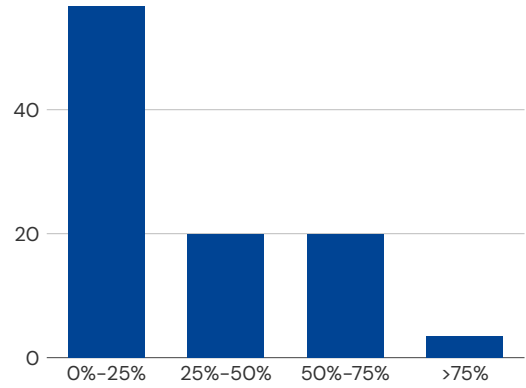
Figure A5.4

Liquidity and financial stability

a) Liquidity in euro area secondary sovereign bond markets
(share of respondents, in %)



b) Probability of major financial stability event over next 12 months
(share of respondents, in %)

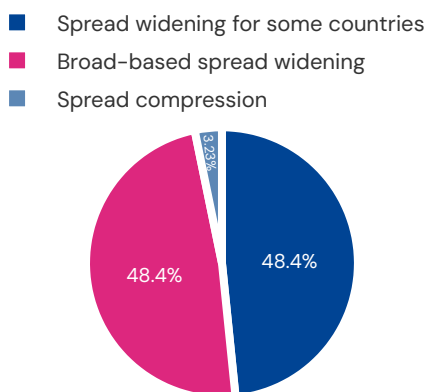


Source: ESM Sovereign Sentiment Survey, Q2 2026

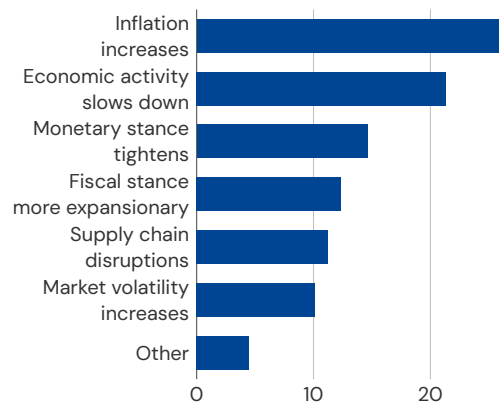
Figure A5.5

Consequences of adverse events for euro area

a) Expected euro area sovereign spread reaction to adverse events
(share of respondents, in %)



b) Consequences of Iran war for euro area sovereign bond markets and economy
(share of respondents, in %)

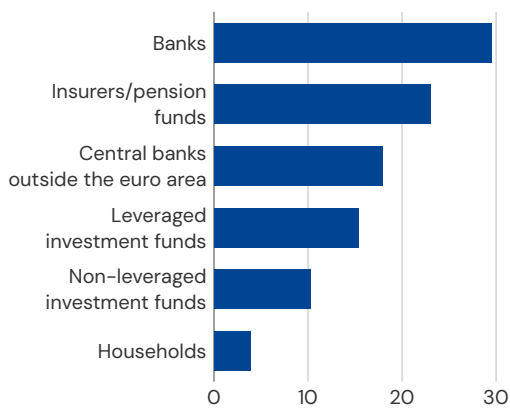


Source: ESM Sovereign Sentiment Survey, Q2 2026

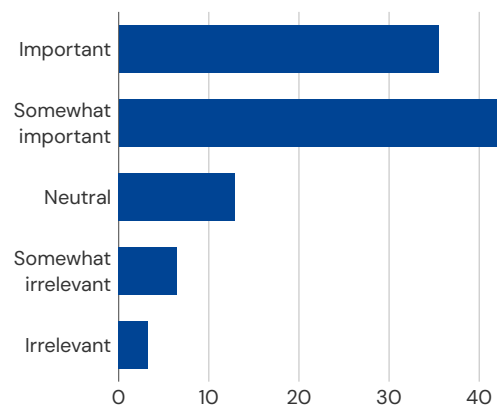
Figure A5.6

Euro area sovereign bond issuance

a) Absorption of euro area sovereign bond net issuance
(share of respondents, in %)



b) Relevance of permanent European Union safe asset for euro area capital markets
(share of respondents, in %)

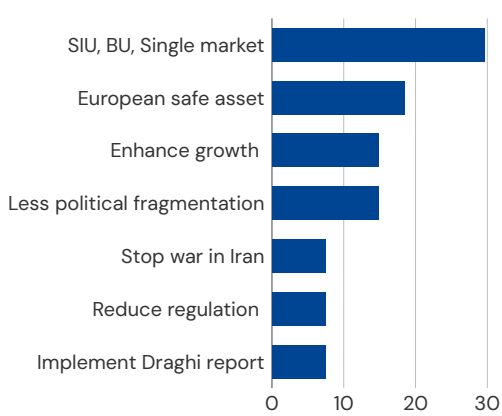


Source: ESM Sovereign Sentiment Survey, Q2 2026

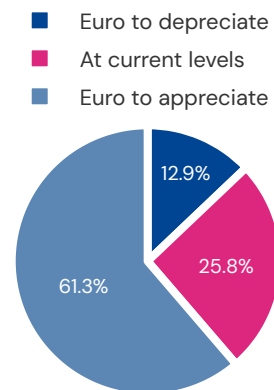
Figure A5.7

Euro area assets in an international context

a) Necessary factors to achieve foreign capital inflows into euro area
(share of respondents, in %)



b) Direction of EUR/USD exchange rate in 12 months
(share of respondents, in %)



Note: SIU stands for savings and investments union. BU stands for banking union.
Source: ESM Sovereign Sentiment Survey, Q2 2026

A6 Methodological notes on the macroeconomic adverse scenario

A6.1 Overview of the modelling framework

This annex describes the framework used to design and quantify the adverse macroeconomic scenario underpinning the risk assessment in [Chapter 1](#). It documents the modelling toolkit, identification strategies, and calibration assumptions used to translate the underlying risk narrative into a consistent set of macroeconomic projections.

The scenario is constructed relative to a baseline consistent with the European Commission's spring 2026 economic forecast, which sets the starting point for all variables. A no-policy-change assumption is imposed, whereby neither monetary nor discretionary fiscal policy respond to the materialisation of adverse shocks beyond what is already embedded in the baseline or implied by automatic stabilisers. As a result, the scenario isolates the macroeconomic effects of the identified risk factors.

The modelling strategy follows a top-down, multi-layered approach. The adverse scenario is developed first at the euro area level and subsequently translated into country-specific projections, ensuring consistency between aggregate and national outcomes. The scenario reflects the joint materialisation of the three risk layers discussed in Chapter 1: persistently high geopolitical tensions and energy prices, a repricing of financial assets of the United States (US), and second-round effects on inflation. Given the multi-dimensional nature of the risks considered, the framework relies on a set of complementary models. Each model captures a specific risk layer or transmission channel, rather than a one-size-fits-all model. Their outputs are combined to derive a single internally consistent macroeconomic path.

The framework proceeds in three main steps ([Figure A6.1](#)):

1. First, the short-term euro area impact (2026–2027) is quantified. This step translates the identified risk layers of the adverse scenario (rise in geopolitical risks and energy prices, repricing of US assets, and second-round effects on inflation) into macroeconomic outcomes. To calibrate the different shocks and capture the relevant transmission channels, the analysis draws on a combination of empirical and structural models, including factor-augmented vector autoregressions (FAVAR), Bayesian vector autoregressions (BVAR), and dynamic stochastic general equilibrium (DSGE) models. The resulting effects on growth and inflation reflect the joint contribution of the impacts of each of three risk layers.
2. Second, the scenario is extended to the medium to long term (2028–2035). Persistent geopolitical tensions and higher energy prices are assumed to weigh on productivity and external competitiveness, generating scarring effects on output. These channels are quantified using empirical (BVAR) and semi-structural models to derive a medium- to long-term trajectory for gross domestic product (GDP)

consistent with the adverse environment described above. Other shocks, particularly those related to US asset repricing, are assumed to have temporary effects and therefore do not materially affect long-term dynamics.

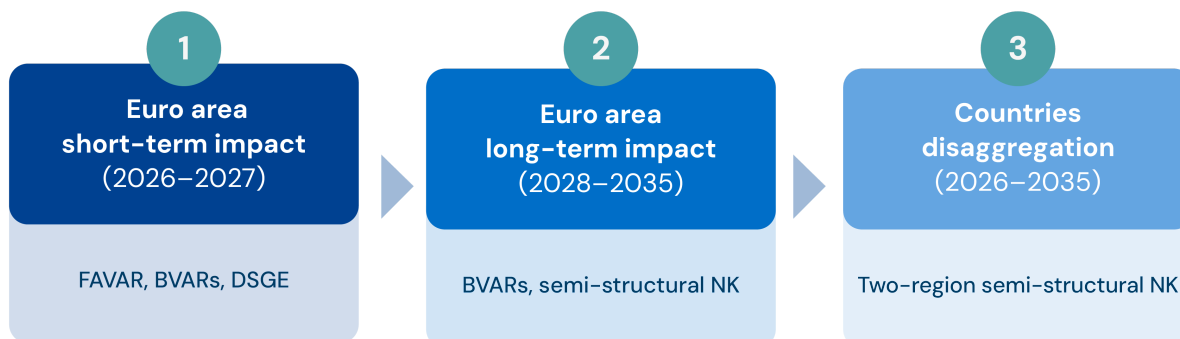
- Third, the euro area adverse scenario is translated into country-specific projections. This is done using a set of two-region open-economy semi-structural New Keynesian (NK) models, which link each member state to the rest of the euro area. This approach allows for heterogeneity in exposure and transmission while maintaining consistency with the aggregate scenario and the underlying risk narrative.

Throughout the framework, real GDP and inflation are the primary variables of interest. They summarise the macroeconomic impact of the adverse scenario and provide the basis for the assessment of fiscal and financial implications in [Chapter 1](#).

The remainder of the annex follows this structure. [Section A6.2](#) presents the short-term euro area scenario. [Section A6.3](#) describes its extension to the medium and long term. [Section A6.4](#) explains the derivation of country-level projections. A summary table of the key conditioning assumptions used in the calibration is provided at the end of the annex ([Table A6.1](#)).

Figure A6.1

Design and quantification of the adverse scenario: a three-step approach



Source: ESM

A6.2 Euro area short-term impact (2026–2027)

This section describes the modelling approach to the short-term adverse scenario for the euro area. The scenario is constructed by aggregating the estimated impacts of the three risk layers, each modelled using a tailored approach ([Figure A6.2](#)).

Geopolitical tensions and energy prices: non-linear Bayesian FAVAR model

To assess the macroeconomic and financial impact of geopolitical risks and energy shocks on the euro area economy, we employ a non-linear Bayesian FAVAR. The model

is described in Capolongo et al. (2026), in the spirit of Brignone et al. (2025). It summarises a large cross-section of macroeconomic and financial variables through 11 latent factors extracted via principal components from a panel covering 10 euro area economies and six other major advanced economies.³ The panel comprises country-level national accounts, prices, trade, financial indicators, and sovereign spreads as well as global indices, including wholesale commodity prices.⁴ The model is estimated at monthly frequency from January 2000 to June 2026. Results are eventually converted into quarterly frequency.

In a first step, we identify structural shocks using a Cholesky decomposition of the FAVAR. The identified structural shocks are used to calibrate the paths for four variables: wholesale oil and gas prices, an ESM proprietary energy geopolitical risk index, and a euro area geopolitical risk index (following the approach of Caldara and Iacoviello, 2022). The identification strategy imposes the restriction that contemporaneous innovations to observed variables (geopolitical risk indices and energy prices) are not driven by shocks to the remaining macro-financial panel within the same period.

In a second step, the identified structural shocks enter as exogenous regressors in a non-linear FAVAR with exogenous variables (FAVARX). Each variable is included both in linear and in squared terms. This specification follows the non-linear FAVAR with exogenous variables (FAVARX) framework, extending the methodology of Forni and Gambetti (2024) and Brignone et al. (2025). The linear component captures the standard propagation of each shock, while the squared term captures magnitude-dependent amplification: larger geopolitical or commodity price shocks have a disproportionately stronger impact on the economy than that implied by a linear extrapolation from small shocks. Both stages are estimated with 20,000 posterior draws under a Minnesota prior.

Based on this framework, we run a conditional forecast under a specific geopolitical scenario: a large initial spike during a single month of the forecast horizon (three standard deviations for the oil shock and four standard deviations for each of the two geopolitical risk shocks), followed by moderate persistence at 0.1 standard deviations for five months, after which no further shocks are imposed. This shock profile captures a sudden, severe geopolitical event with a short-lived tail of elevated risk. The framework compares the resulting conditional forecast with the baseline. It attributes forecast movements to individual shocks by passing each shock through the median vector moving-average impulse-response kernels, thereby combining standard linear propagation with non-linear amplification.

US asset repricing: BVAR and DSGE models

Spillovers from a sharp repricing of US assets to the euro area are quantified using a combination of models. In the scenario, the repricing is triggered by a sharp rise in US policy uncertainty. Satellite BVARs are used to calibrate the shock, assess its financial and macroeconomic effects in the US, and trace its implications for euro area financial conditions. In a second step, these results are mapped into euro area macroeconomic outcomes using a DSGE framework.

We assess the macro-financial impact of a rise in policy uncertainty and repricing of US assets with a BVAR model tailored towards US macroeconomic and financial variables. The model comprises the ESM proprietary economic policy uncertainty (EPU) index for the US, the VIX (an option-implied measure of US stock market volatility), the S&P500, the 10-year overnight index swap (OIS) yield, the federal funds rate, the excess bond premium,⁵ employment, inflation, GDP, consumption, investment, the EUR/USD exchange rate, the Euro Stoxx 600, and the 10-year German government bond yield. It is estimated at quarterly frequency starting in Q1 1996 and ending in Q4 2025. The macroeconomic variables are considered in real terms. Based on this model, we run a conditional forecast, conditioning on a path for the EPU, the VIX, the OIS spread, and the excess bond premium to extract the relevant shocks aligned with our narrative.

We use a separate BVAR to explore implications for euro area borrowing conditions. The variables in the model comprise the US EPU index, the VIX, the excess bond premium for the US, the S&P500, the Euro Stoxx 600, the BBB spread for the euro area, the 10-year German government bond yield, the Euribor, the spread between the lending rate (non-financial corporations) and the Euribor, and the increase in bank loans to non-financial corporations (deflated). The model is estimated over a slightly shorter period due to data availability constraints for euro area loan data (from Q1 2001 to Q2 2025). A conditional forecast is conducted by conditioning on the paths of US variables derived from the US-focused BVAR.

The final impact on the euro area economy of both financial and trade channels is obtained by combining the results of two separate simulation exercises:

- To assess the macroeconomic implications of financial amplification in the euro area, the resulting paths are fed into a macro-financial euro area DSGE model. Specifically, the paths for credit spreads, the loan spread, credit growth, and interest rates from the euro area markets' BVAR are included in a DSGE model like the one described in Kühl (2018). The model is estimated for the euro area (closed economy) and has an emphasis on financial amplification via an elaborate financial sector.
- In addition, to capture the trade channel of transmission to the euro area, we use a three-region DSGE model for an open economy following Cardani et al. (2023). The model features the euro area, the US, and the rest of the world. The model emphasises trade linkages. We run a conditional forecast, conditioning on the US macroeconomic variables that result from the first step BVAR approach. We simulate the impact on the euro area economy while keeping euro area interest rates unchanged.

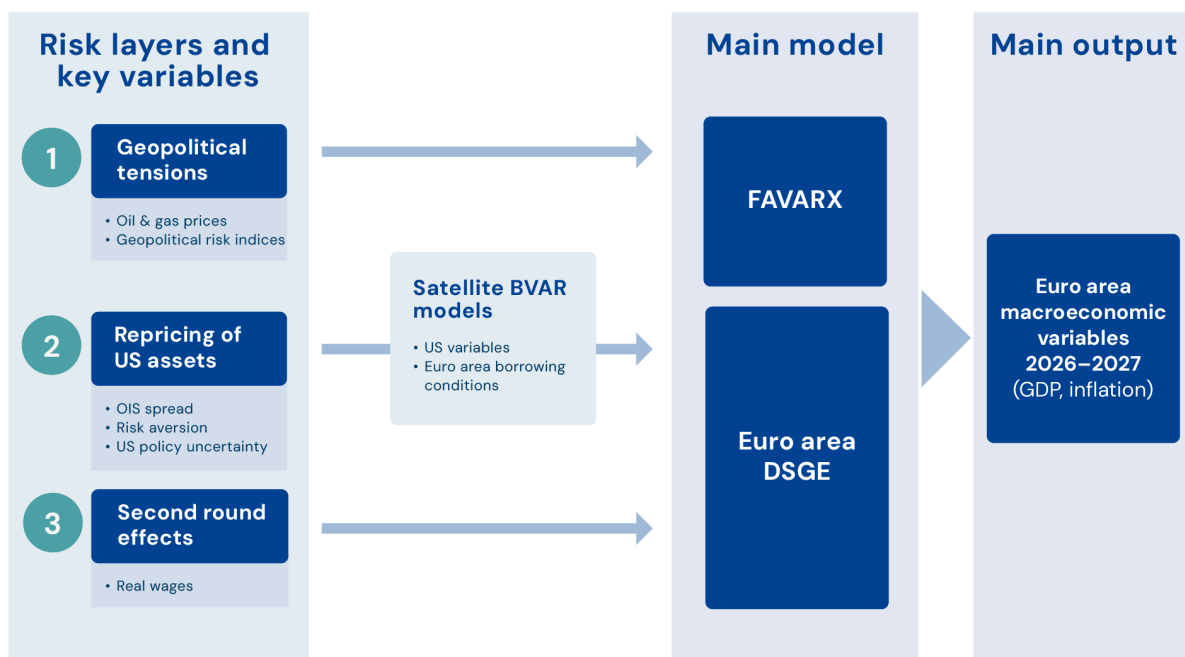
Second-round effects on inflation: DSGE approach

The second-round effects on inflation from the rise in energy prices are assessed by using the macro-financial DSGE model for the euro area. A conditional forecast is conducted targeting real wage growth reflecting recent experience. Specifically, it is assumed that workers can negotiate higher wages (around one percentage point higher wage growth than otherwise), which is implemented in the model with a wage mark-up

shock. Real wages in the adverse scenario are therefore higher than when abstracting from second-round effects.

Figure A6.2

Schematic representation of short-run modelling approach



Source: ESM

A6.3 Euro area medium- to long-term impact (2028–2035)

This section explains how the short-term adverse scenario is translated into medium- to long-run macroeconomic paths for the euro area. The approach combines evidence on the persistent effects of geopolitical and energy price shocks on productivity and external competitiveness (Section A6.2) with a semi-structural framework. This framework allows us to map these long-run forces into a coherent path for a broader set of macroeconomic variables.

GDP scarring via impaired innovation and export-sector productivity: BVAR

The long-term impact of persistently high geopolitical tensions is identified using a BVAR model and a combination of sign and zero restrictions (Furlanetto et al., 2025; Bratsiotis and Theodoridis, 2022). The model comprises oil and gas prices, geopolitical risk, and the following variables for the euro area: real GDP, inflation, real investment, the relative price of investment, unemployment, the 10-year government bond yield, real wages, investment in research and development as a share of GDP, and total factor productivity. All series are expressed in log levels, except for research and development. The model is

estimated using quarterly data from Q1 1999 to Q4 2025, two lags are specified, and a Minnesota-type prior is used to facilitate estimation. To identify the shock of persistently elevated geopolitical tensions, we assume it has zero contemporaneous impact on oil and gas prices, suppresses investment in physical capital and research and development in the short run, and has a permanent impact on total factor productivity and relative price of investment.

The identified shock captures the narrative that persistent uncertainty discourages corporates from investing in innovation. This harms productivity not only in high-productivity sectors but across the economy. Neither the sign nor the magnitude of the shock's effect on GDP are restricted, letting the data determine the shock's statistical and economic significance for economic activity. Once the shock is identified, its effect on GDP is calculated by conditioning on short- and long-term oil and gas prices and the geopolitical risk profiles presented in [Table A6.1](#) at the end of the document, and the GDP path of the short-term adverse scenario between Q3 2026 and Q4 2027 discussed in the previous section ([Section A6.2](#))

The second shock, a deterioration of export-sector productivity, is proxied by a persistent increase in the ratio of export prices to the GDP deflator. In the spirit of Schmitt-Grohe and Uribe (2025) and Gortz et al. (2022), we employ state-space estimation techniques to identify the long-run effect of a permanent increase in the ratio of export prices to the GDP deflator (RPX) on GDP. Given that the RPX for the euro area displays a pronounced downwards sloping trend, we assume that euro area potential supply is driven by two stochastic trends: the (standard) economy-wide trend and an export-specific technological trend. The second technological trend operates within the export sector, expanding at a faster pace than the rest of the economy, consistent with the downward trend in RPX.

We use a two-sector open-economy DSGE model to identify the shares of the two trends in the economy. The approach followed is like Gortz et al. (2022). The model comprises real GDP growth, real export growth, and RPX growth. It is estimated using quarterly data from Q1 1970 to Q4 2025. Two lags are included to capture cyclical dynamics, and prior information is incorporated in the form of a Minnesota-type prior.⁶ Finally, the shock is calibrated by gradually unwinding the reduction in the RPX the European Commission foresees over the forecast horizon (European Commission spring 2026 economic forecast).

Taken together, these two channels – innovation and export-sector productivity – drive the medium- to long-term impact on GDP.

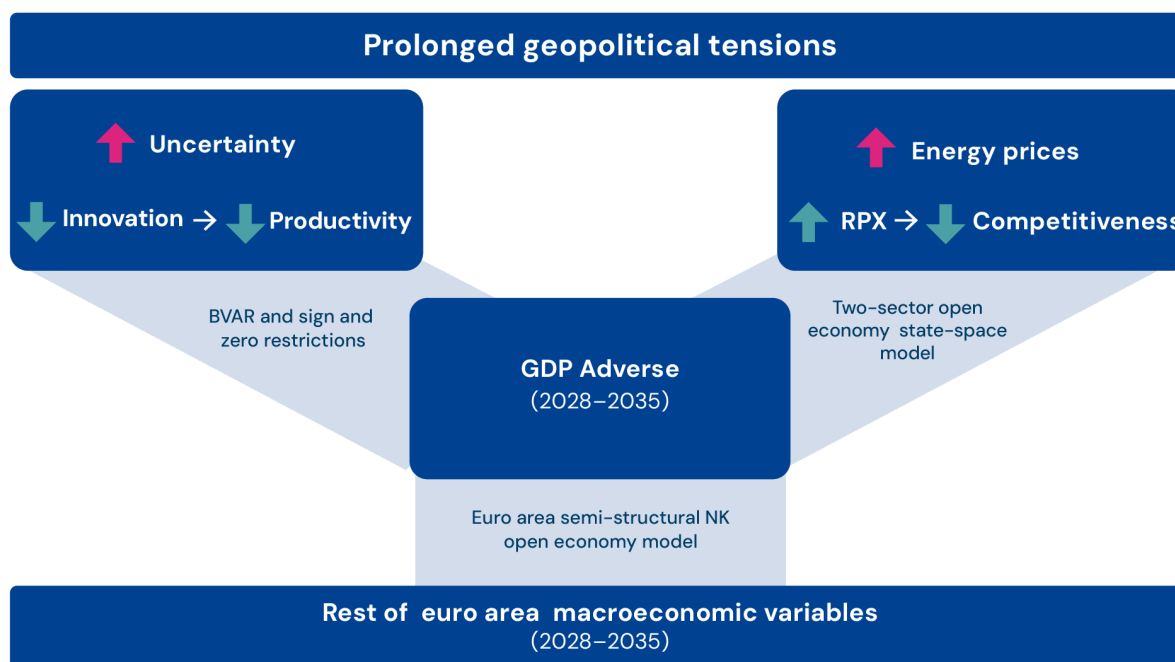
Broader macroeconomic long-term effects: semi-structural model

The medium- to long-run profiles of all variables other than GDP are derived using an open-economy semi-structural NK economic model. Similar to Angelini et al. (2019), a semi-structural macroeconomic NK open-economy model is developed to reconcile the short- and long-term baseline forecasts produced by the European Commission. This also helps assess how alternative assumptions impact the evolution of key series of

interest. The model features nominal, real, and financial frictions. The model is estimated with Bayesian maximum likelihood techniques on data from Q1 1995 to Q4 2025.

Figure A6.3

Schematic representation of medium-term risks and modelling approach



Note: RPX is the ratio of export prices to the GDP deflator.

Source: ESM

The semi-structural model generates internally consistent paths for the remaining economic variables conditional on the short-term scenario and long-run restrictions. Given the conditioning assumptions reported in [Table A6.1](#), the short-term (T+1 and T+2) profiles of the economic variables explained in [Section A.6.2](#) and the estimated T+3 to T+10 GDP paths, the model derives conditional forecasts for all other economic variables over the T+3 to T+10 horizon. This ensures that the resulting T+10 scenario extends captures the broader macroeconomic environment in a way that is coherent with the overall adverse narrative.

A6.4 Euro area countries (2026–2035)

With the euro area medium- to long-run impact of the adverse scenario quantified, the next step is to translate it into country-specific paths. This requires a framework that preserves consistency with the aggregate euro area outlook while allowing for heterogeneity in trade and country-specific exposures, fiscal space, and domestic propagation mechanisms.

The medium- to long-run profiles of country-specific economic variables are produced using a two-region open-economy semi-structural NK economic model. The model mentioned in the [Section A6.3](#) is further extended into a two-region model comprising the country of interest and the rest of the euro area for each of the euro area member states. From the country's perspective, trade and financial transactions occur with both the rest of the euro area and the rest of the world.

The two-region structure allows each country's outlook to be conditioned on the euro area adverse scenario while preserving country-specific transmission mechanisms. In this way, the country scenarios remain consistent with the aggregate euro area narrative but are not constrained to react identically across jurisdictions.

Country-specific adverse scenarios for T+1 to T+10 profiles are produced in two steps. In the first step, country-specific forecasts are derived conditional on the T+1 to T+10 euro area profiles discussed in [Section A6.3](#). In a second step, the resulting country profiles are reviewed to determine whether country-specific forecasts align with the narrative adopted. For example, persistently higher oil and gas prices should have more severe effects in countries that rely more heavily on fossil fuels and have more limited fiscal space. If this is not the case, then further iterations are undertaken to align the resulting profiles with the judgement of country experts and the euro area risk narrative. This iterative procedure is intended to ensure that the final country paths are aligned with both country-specific expertise and the broader scenario narrative. The result is therefore a set of country projections that is both model-consistent and tailored to the structural characteristics and vulnerabilities of each jurisdiction.

Strengths and limitations of the framework

The main strength of the framework is that it combines empirical grounding with structural discipline. Empirical models use data-rich information sets to identify shocks and measure spillovers, while structural models map these shocks into internally consistent macroeconomic outcomes. This design is well suited to adverse scenarios in which non-linear amplification, trade spillovers, and financial frictions all matter. The multi-layered approach also allows the contribution of individual risk layers to be traced and communicated clearly.

At the same time, the framework also carries limitations. Combining outputs across models with different samples and identifying assumptions introduces aggregation uncertainty. To address this, cross-model consistency and coherence with the scenario narrative are used as organising principles throughout the exercise. Long-run projections are additionally sensitive to assumptions about the persistence of scarring effects. All these considerations suggest the results are best interpreted as one plausible adverse path, to be read alongside the qualitative risk narrative in [Chapter 1](#).

Table A6.1

Key variables for designing the adverse macroeconomic scenario

Key variable	Calibration	
	Short term	Long term
Oil prices	USD 100/barrel on average in 2026, and USD 87 /barrel in 2027	USD 87/barrel in 2028–2035
Gas prices	€57/megawatt-hour on average in 2026, and €49/megawatt-hour in 2027	€49/ megawatt-hour in 2028–2035
Geopolitical risks	70% and 20% above baseline in 2026 and 2027, respectively	20% above baseline in 2028–2035
Energy-related geopolitical risks	100% and 30% above baseline in 2026 and 2027, respectively	
US 10-year yield-OIS spread	Rising to 60 basis points in 2026 falling to 56 basis points in 2027	
US excess bond premium	Gradual increase by 50 basis points reached mid-2027	
US policy uncertainty index	Around 100% above current level by end-2026	

Key variable	Calibration	
	Short term	Long term
VIX	Around 60% above baseline by end-2026	
EUR/USD	Appreciation of the euro by around 2% by end-2027	
US 10-year government bond yields	Peak increase of around 80 basis points in 2027	
German 10-year government bond yields	Increase of around 30 basis points by end-2027	It is kept constant at 30 basis points over baseline
S&P500	Almost 20% lower by end-2027	
EURO STOXX	Almost 30% lower by end-2027	

Source: ESM calculations

A6.6 References

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A7 Constructing the baseline and adverse fiscal scenarios

A7.1 Objectives

This note describes the methodology used to construct the fiscal scenarios presented in [Chapter 1](#). These scenarios are designed to assess the fiscal implications of the adverse macroeconomic scenarios specified in [Section 1.4](#) of [Chapter 1](#).

This note also explains the approach used to estimate fiscal adjustment needs under the economic governance framework of the European Union (EU). In this context, the scenarios serve to gauge the scale of policy effort that may be required to place public debt on a plausibly downward trajectory or to ensure that it remains at prudent levels.

A7.2 Baseline scenario based on the European Commission framework with defence spending

The baseline scenario constitutes the central path for the analysis and serves as the benchmark for assessing the adverse scenario. In the short term (2026–2027), the

baseline fiscal scenario is aligned with the European Commission's 2026 spring economic forecast (published on 21 May 2026). Beyond the short-term horizon, projections are extended using the European Commission's methodology underpinning the Debt Sustainability Monitor (European Commission, 2026).

This approach breaks down the primary fiscal balance into three components:

1. the structural primary balance net of ageing costs, which remains constant at its value forecast for T+1, while ageing-related expenditure covering pensions, healthcare, long-term care, and education enter as projected in the joint European Commission-Council of the EU 2024 Ageing Report (as well as property income from government assets);
2. the cyclical component, which is determined by the output gap and country-specific budgetary semi-elasticities; and
3. one-off and other temporary measures, which are set to zero beyond T+2, in line with a no-policy-change approach.

Under the baseline scenario, interest rates follow the same methodological approach as the European Commission. For 2026 and 2027, market interest rates are computed using the same reference period of the European Commission spring 2026 economic forecast. Interest rate projections then follow the European Commission's methodology underpinning the Debt Sustainability Monitor (European Commission, 2026) which interpolates between market spot rates and 10Y10Y forward rates.

A7.3 Adverse scenario

The ESM's adverse fiscal scenario builds on the adverse macroeconomic scenario described in [Chapter 1](#) and incorporates the effects of governments' military spending commitments. To reflect the sizeable expenditure pressures stemming from countries' commitments to raise defence spending, the structural primary balance net of ageing costs is adjusted to include additional military expenditure sufficient for each country to reach the North Atlantic Treaty Organisation (NATO) target of 3.5% of gross domestic product (GDP) by 2035. In effect, the scenario treats the gap to the NATO target in the same way as ageing costs, namely as spending pressures that worsen fiscal balances if no other policy changes take place.

The military expenditure trajectory is based on the information provided in the European Commission's 2026 spring package, which includes expenditure plans up to 2026. Using the 2026 level of military expenditure as the starting point, additional increases are assumed from 2027 onwards. The trajectory is calibrated to fully utilise the flexibility provided under the national escape clause until 2028, allowing defence expenditure to increase by up to 1.5 percentage points of GDP without breaching the EU fiscal rules.

Thereafter, military expenditure is assumed to increase linearly until reaching the NATO benchmark of 3.5% of GDP by 2035. The benchmark applies to all euro area countries.

For non-NATO euro area countries, the 3.5% of GDP benchmark is an analytical assumption rather than a formal policy commitment.

Structural primary expenditures are assumed to grow in line with baseline nominal potential GDP growth. This therefore constitutes a no-policy-change scenario, in which the government maintains baseline policies without adjusting expenditure in response to the weaker macroeconomic environment. The change in the structural primary balance (SPB) under the adverse scenario is therefore given by

$$\Delta SPB_t = \frac{\text{Primary Expenditure}}{\text{GDP}} \cdot \left(g_t^{\text{Pot, Adverse}} - g_t^{\text{Pot, Baseline}} \right)$$

where g_t^{Pot} denotes nominal potential GDP growth. Lower potential growth in the adverse scenario therefore leads to a mechanical deterioration in the structural primary balance at unchanged policies.

The cyclical component of the primary balance adjusts to reflect the updated output gap estimates derived from the adverse macroeconomic scenario. Compared to the baseline, the output gap closes more gradually under the adverse,⁷ thereby prolonging the cyclical drag on public finances.

The overall primary balance is then obtained by adding ageing-related expenditure and property income on government assets. Both components are assumed to evolve in line with the baseline scenario. Taken together, all these factors result in persistently weaker primary balances under the adverse scenario compared to the baseline scenario.

Finally, interest rate projections in the adverse scenario reflect the impact of the different risk layers on government bond yields (Section 1.4 of Chapter 1). In the short term (2026–2027), deviations of German government bond yields from the baseline path are derived from the modelling of the adverse macroeconomic scenario (Section 1.4 of Chapter 1 and Annex A6). For other euro area countries, sovereign bond spreads vis-à-vis German government bond yields are estimated using a simplified structural scenario analysis tool (cf. Antolin-Diaz et al., 2021). This tool relies on a monthly panel regression model linking sovereign spreads to macroeconomic, fiscal, monetary, and global financial variables that capture credit risk, liquidity risk, and overall risk aversion. As the effects of external shocks gradually fade, sovereign spreads are estimated considering the evolution of country-specific fiscal variables.

A7.4 Fiscal adjustment under the European economic governance framework

Assumptions underlying fiscal adjustment paths

The analysis of adjustment needs under the European economic governance framework focuses on the fiscal effort required in the second round of medium-term fiscal-

structural plans. The second round starts after 2028, to ensure compliance with the fiscal rules while accommodating the increase in military spending (Council of the European Union, 2024).

In the current round of medium-term fiscal-structural plans (2027–2028), we assume that countries increase their net expenditure in line with Council recommendations, taking full advantage of national escape clauses. Thereafter, a debt sustainability analysis is conducted for all countries, assuming that each country requests a seven-year adjustment period under the EU fiscal framework as this is the permissible extended period available to Member States. The adjustment needs are determined by compliance with the debt sustainability criterion, ensuring that public debt is placed on a plausibly downward trajectory. Given the stylised nature of the exercise, however, compliance with the debt sustainability safeguard, which requires a minimum reduction in the debt ratio for countries with public debt above 60% of GDP, and the deficit resilience safeguard, which requires maintaining a fiscal buffer below the 3% of GDP deficit reference value, are not imposed as additional criteria.

This approach explicitly accounts for the additional fiscal adjustment required to accommodate long-term spending pressures from defence and ageing, while also reflecting the impact of weaker macroeconomic performance on fiscal positions relative to the baseline.

Decomposition of fiscal adjustment needs

This section clarifies our definition of fiscal adjustment and provides a decomposition to identify the adjustment needed to offset the deterioration in fiscal outcomes arising from adverse macroeconomic conditions, demographic pressures, and military expenditure commitments.

Let $\Delta SPB_t^{X,Scen}$ denote the annual change in the structural primary balance in year t , where $X \in \{Adj, NPC\}$ refers to the path of the structural primary balance consistent with the fiscal rules and no-policy-change, while $Scen \in \{Baseline, Adverse\}$ denotes the macroeconomic scenario.

We define the adjustment required under the fiscal rules relative to the no-policy-change scenario over the period 2026–2035 as:

$$\text{Adjustment}^{Scen} = \sum_{t=2026}^{2035} \left(\Delta SPB_t^{Adj,Scen} - \Delta SPB_t^{NPC,Scen} \right).$$

Under the no-policy-change scenario, the structural primary balance deteriorates mechanically because increases in military expenditure and ageing-related costs are not offset by policy measures. Achieving the target fiscal position implied by the fiscal rule requires discretionary measures to compensate for these expenditures. This distinction is analytically important. If adjustment was measured excluding these expenditures, we

would understate the actual consolidation effort required to comply with the fiscal framework.

Denoting by $\check{S}\check{P}B$ the structural primary balance excluding military expenditures and cost of ageing, the adjustment can be decomposed as:

$$\begin{aligned} \text{Adjustment}^{\text{Scen}} = & \sum_{t=2026}^{2035} \left(\Delta SPB_t^{\text{Adj,Scen}} - \Delta \check{S}\check{P}B_t^{\text{NPC,Scen}} \right) + \\ & \sum_{t=2026}^{2035} \Delta \text{Military}_t + \sum_{t=2026}^{2035} \Delta \text{CoAg}_t. \end{aligned}$$

This decomposition isolates the contribution of military expenditure and ageing costs to total adjustment requirements.

Under the adverse scenario, the first term can be further decomposed as:

$$\begin{aligned} & \sum_{t=2026}^{2035} \left(\Delta SPB_t^{\text{Adj,Adverse}} - \Delta \check{S}\check{P}B_t^{\text{NPC,Baseline}} \right) + \\ & \sum_{t=2026}^{2035} \left(\Delta \check{S}\check{P}B_t^{\text{NPC,Baseline}} - \Delta \check{S}\check{P}B_t^{\text{NPC,Adverse}} \right). \end{aligned}$$

The first term captures the distance between the target structural position under the rule at the end of the adjustment horizon and the corresponding structural position under no-policy- change, excluding military expenditure and the cost of ageing. The second term singles out the additional consolidation required solely to offset the deterioration in fiscal outcomes caused by weaker macroeconomic conditions under unchanged policies.

The maximum realised historical adjustment is calculated as the largest improvement in the cyclically adjusted primary balance (CAPB) recorded during a qualifying fiscal consolidation episode over the period 1995–2025. The analysis starts in 1995, as CAPB data are not available for a sufficiently large number of countries before that date. A qualifying fiscal consolidation episode is defined as a period in which the CAPB improves in each year of the episode and cumulatively by at least two percentage points of GDP over two years or by at least three percentage points of GDP over three or more years (Callegari et al., 2025). The consolidation episodes for Greece, Portugal and Ireland during financial assistance programmes are excluded.

A7.5 References

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A8 Methodological notes on fiscal space scores

This annex presents the framework used in [Chapter 1](#) to assess fiscal space across euro area countries. Fiscal space is measured using a composite indicator of projections of four core fiscal variables. The objective of this indicator is to provide a transparent and internally consistent measure of countries' relative fiscal space under both the baseline and the adverse macroeconomic scenario. The proposed framework reflects ongoing work and is intended for cross-country comparison in the euro area under different scenarios.

A8.1 Fiscal space and its determinants

Fiscal space reflects the interplay of several dimensions of a government's fiscal position. Fiscal space is understood as the capacity of a government to adjust spending or taxes while preserving sound public finance. It is inherently multi-dimensional, as it encompasses considerations related to debt sustainability, fiscal position, and flexibility (Kose, Kurlat, Ohnsorge, and Sugawara, 2022; IMF, 2018). To capture these dimensions in a transparent and tractable manner, the analysis focuses on four indicators, each capturing a distinct and complementary dimension of fiscal space.

- The government debt-to-revenue ratio measures the burden of public debt relative to the government's capacity to generate income. Debt measured relative to the tax base provides an informative measure of fiscal space because it links public

debt to the resources available for servicing and managing that debt (Aizenman, Jinjarak, Nguyen, and Park, 2019).

- The budget balance, measured as the overall general government balance as a share of gross domestic product (GDP), reflects the underlying fiscal position and the degree to which a government is adding to or reducing its debt stock.
- Fiscal flexibility, defined as the difference between total revenue and rigid expenditure expressed as a share of total revenue, captures the proportion of government revenues that can be actively deployed. Rigid expenditures, such as on pensions, interest payments, and compensation of employees, are difficult to adjust in the short run; a government with limited flexibility has little room to manoeuvre even if its overall fiscal position appears adequate.
- The interest-growth differential is measured in nominal terms and captures the dynamic of public debt accumulation by comparing the cost of borrowing to the pace of economic growth.

A8.2 Technical calculations

All indicators are standardised using z-scores. For each of the four fiscal indicators, z-scores are computed separately using the cross-country distribution of the indicator across euro area countries in the 2028 baseline scenario as the reference benchmark. The 2028 values are based on ESM scenario calculations, anchored in European Commission projections. The 2028 horizon is used because the fiscal impact of the adverse shock materialises with a lag, once the initial inflationary pressures fade: as inflation normalises, the loss in potential GDP translates into a deterioration in the structural balance (see [Annex A7](#) for further details).

Standardisation allows comparing the relative ranking of countries along the four dimensions of fiscal space. Prior to the calculation, each variable is sign-adjusted so that higher values consistently reflect an improvement in fiscal space. Formally, for each indicator i and country c , the standardised score is computed as

$$z_{i,c} = \frac{(x_{i,c} - \mu_i)}{\sigma_i}$$

where $x_{i,c}$ denotes the raw value of the indicator based on 2028 baseline projection values, and μ_i and σ_i are the cross-country mean and standard deviation in the 2028 baseline scenario. For each country, the z-score measures the distance of the indicator from the baseline cross-country distribution, expressed in standard deviation units.⁸ A value of zero indicates that the country is at the euro area average, while positive (negative) values indicate a stronger (weaker) position relative to the average.

In the adverse scenario, the z-score compares country projections under the adverse scenario to those under the baseline. Specifically:

$$z_{i,c}^{adv} = \frac{(x_{i,c}^{adv} - \mu_i^{baseline})}{\sigma_i^{baseline}}$$

Keeping the baseline benchmark fixed allows changes between the baseline and adverse scenarios to be interpreted as changes in fiscal space relative to the same reference distribution. A deterioration in the underlying fiscal indicators under the adverse scenario is therefore reflected in lower z-scores. This reflects the intuitive and empirically supported result that fiscal space contracts under adverse conditions (Ghosh, 2013).

The composite fiscal space score is then calculated as the simple average of the four standardised indicators:

$$FS_c = \frac{1}{4} \sum_{i=1}^4 z_{i,c}$$

All indicators are equally weighted. For ease of interpretation, the composite fiscal space score is additionally mapped into a 0-100 index using the cumulative normal distribution. Specifically, the index is defined as $100 \times \Phi(z)$, where Φ denotes the standard normal cumulative distribution function. Under this transformation, a value of 50 corresponds to the euro area average, while higher (lower) values indicate more (less) fiscal space. This transformation is monotonic and does not affect country rankings or underlying results.

A8.3 Classification and interpretation

For ease of interpretation, countries are grouped into three categories based on their composite score, as shown in [Table A8.1](#). For presentation purposes, results are expressed using the 0-100 fiscal space index. The classification thresholds correspond directly to the underlying z-score cutoffs: countries with an index value of 16 or below are classified as having limited fiscal space, those with values between 16 and 84 as having some fiscal space, and those above 84 as having ample fiscal space. These thresholds correspond to z-scores of -1 and +1, respectively.⁹

The baseline results show each country's position relative to the euro area average under baseline conditions (in T+3). The adverse results show how the same country performs under stress in T+3, still evaluated against the baseline benchmark. This allows

differences between scenarios to be interpreted directly as deterioration or improvement in fiscal space relative to baseline conditions.

A8.4 Caveats

Being a relative measure of fiscal space, the composite indicator abstracts from common factors that determine fiscal space in an absolute sense, such as investor risk appetite, global financial conditions, and euro area monetary policy. Furthermore, the interpretation of z-scores assumes that the underlying distribution of indicators is reasonably well-behaved, such that standard deviation is an informative measure of dispersion.

The relationship between fiscal space and medium-term adjustment needs is presented in [Figure A8.1](#) as a validation exercise for the composite indicator. Conceptually, countries that already require larger fiscal adjustments should have more limited fiscal space as weaker fiscal positions constrain their ability to absorb shocks or sustain current policies. Furthermore, while adjustment needs are sometimes considered a potential component of fiscal space measures, the strong negative correlation observed in the data suggests that the current indicator already captures this dimension indirectly. Countries assessed as having more limited fiscal space tend, in practice, to face larger adjustment requirements. This suggests that the fiscal space measure proposed here reflects economically meaningful constraints.

Table A8.1

Grouping of countries based on fiscal space indicators

Country	Baseline index	Adverse index
Ireland	97 ●	87 ●
Cyprus	89 ●	73 ●
Malta	87 ●	64 ●
Netherlands	87 ●	76 ●
Luxembourg	82 ●	70 ●
Croatia	67 ●	44 ●
Germany	59 ●	43 ●
Lithuania	54 ●	14 ●
Slovenia	48 ●	23 ●
Portugal	44 ●	22 ●
Estonia	39 ●	26 ●
Bulgaria	38 ●	15 ●
Greece	35 ●	18 ●
Austria	34 ●	20 ●
Spain	32 ●	10 ●
Latvia	28 ●	14 ●
Slovakia	28 ●	13 ●
Belgium	26 ●	10 ●
Finland	25 ●	15 ●
France	14 ●	5 ●
Italy	8 ●	2 ●

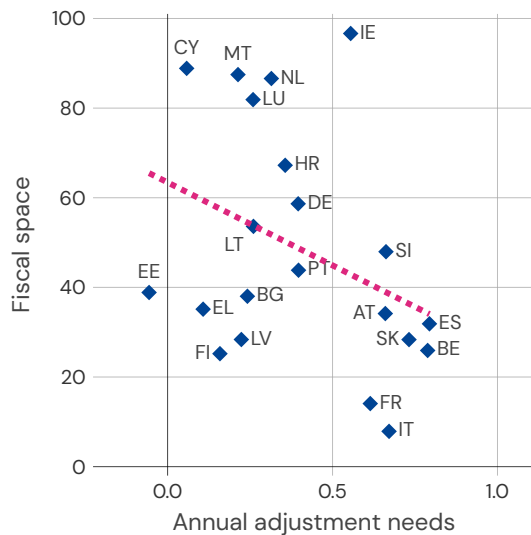
Notes: Countries are classified into three groups: limited (index ≤ 16), some ($16 < \text{index} \leq 84$), and ample fiscal space (index > 84), corresponding to z-score thresholds of -1 and $+1$, and are shown using red, orange and green, respectively. The adverse scenario is evaluated against the same baseline benchmark to ensure comparability. Source: ESM calculation based on European Commission's spring 2026 economic forecast data, Eurostat data, European Commission's spring 2026 package data and the 2024 Ageing Report

Figure A8.1

Fiscal space and adjustment needs: baseline and adverse scenarios

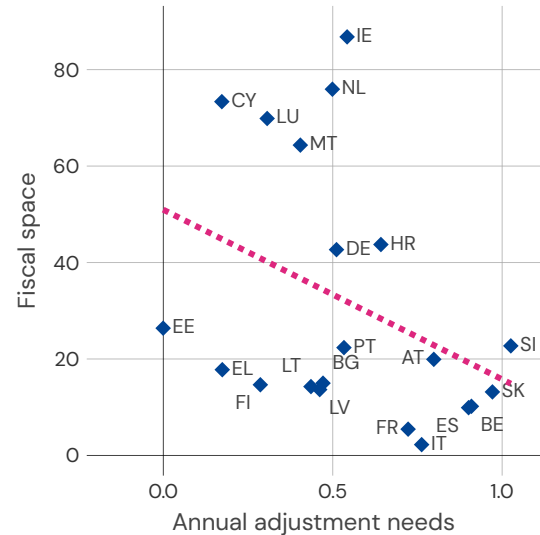
a) Baseline (baseline benchmark)

(x-axis: in percentage points of GDP, y-axis: index)



b) Adverse (baseline benchmark)

(x-axis: in percentage points of GDP, y-axis: index)



Notes: Fiscal space is measured using the composite fiscal space index (0-100 scale, derived from the underlying z-scores), where higher values indicate more fiscal space and 50 corresponds to the euro area average, while adjustment needs correspond to the required annual fiscal effort over 2026–2035. The dashed line shows the fitted linear trend. In both panels, fiscal space is evaluated relative to the 2028 baseline cross-country distribution, ensuring comparability across scenarios.

Source: ESM calculation based on European Commission's spring 2026 economic forecast data, Eurostat data, European Commission's spring 2026 package data and the 2024 Ageing Report

A8.5 Detailed fiscal space results

This section presents the detailed country-level results underlying the fiscal space assessment. It reports the values of the four underlying indicators – debt-to-revenue, budget balance, fiscal flexibility, and the interest-growth differential – as well as the resulting composite fiscal space scores for each euro area country. While the main text presents the 0-100 fiscal space index for ease of interpretation, this section reports the underlying z-scores relative to the 2028 baseline distribution. Results are shown for both the baseline (Table A8.2) and adverse (Table A8.3) scenarios, allowing a direct comparison of fiscal positions under normal conditions and under stress, and its underlying factors. For example, high debt levels and persistent fiscal deficits are the main factors limiting fiscal space in France, whereas Greece's steadily improving budget balance enables it to gain some fiscal space despite having a less favourable debt-to-revenue ratio than France in the baseline scenario. Furthermore, lower growth and higher interest rates further constrain fiscal space for most countries under the adverse scenario.

As robustness checks, fiscal-space scores are also standardised using a historically anchored euro area benchmark for 2002–2024, and classifications are assessed under alternative threshold values. The main patterns remain broadly unchanged, although higher thresholds concentrate more countries in the intermediate category, while lower thresholds produce greater dispersion across high and low fiscal-space groups.

Table A8.2

Grouping of countries based on fiscal space indicators under baseline

Country	Debt to revenue	Budget balance (% GDP)	Fiscal flexibility	Interest-growth	Baseline composite
Austria	-0.20 ●	-0.67 ●	-0.38 ●	-0.38 ●	-0.41 ●
Belgium	-1.30 ●	-1.16 ●	0.08 ●	-0.20 ●	-0.65 ●
Bulgaria	1.07 ●	-0.50 ●	-1.73 ●	-0.07 ●	-0.31 ●
Croatia	0.76 ●	0.03 ●	0.28 ●	0.72 ●	0.45 ●
Cyprus	1.16 ●	2.57 ●	0.37 ●	0.78 ●	1.22 ●
Estonia	1.29 ●	-0.91 ●	-0.41 ●	-1.10 ●	-0.28 ●
Finland	-0.39 ●	-0.74 ●	-1.19 ●	-0.35 ●	-0.67 ●
France	-1.38 ●	-1.37 ●	-0.58 ●	-0.98 ●	-1.08 ●
Germany	0.09 ●	-0.67 ●	1.78 ●	-0.33 ●	0.22 ●
Greece	-1.86 ●	1.48 ●	-0.36 ●	-0.79 ●	-0.38 ●
Ireland	0.64 ●	1.99 ●	2.18 ●	2.52 ●	1.83 ●
Italy	-2.31 ●	-0.14 ●	-1.06 ●	-2.16 ●	-1.41 ●
Latvia	0.40 ●	-0.78 ●	-0.67 ●	-1.24 ●	-0.57 ●
Lithuania	0.52 ●	-0.08 ●	-0.32 ●	0.24 ●	0.09 ●
Luxembourg	1.69 ●	0.82 ●	0.74 ●	0.40 ●	0.91 ●
Malta	0.61 ●	0.57 ●	0.87 ●	2.55 ●	1.15 ●
Netherlands	0.87 ●	0.51 ●	2.99 ●	0.06 ●	1.11 ●
Portugal	-0.69 ●	1.13 ●	-0.89 ●	-0.18 ●	-0.16 ●
Slovakia	-0.12 ●	-1.33 ●	-0.27 ●	-0.56 ●	-0.57 ●
Slovenia	0.26 ●	-0.49 ●	-0.45 ●	0.48 ●	-0.05 ●
Spain	-1.16 ●	0.27 ●	-0.71 ●	-0.28 ●	-0.47 ●

Notes: Fiscal space is measured as the simple average of four sign-adjusted indicators, expressed as z-scores so that higher values indicate more fiscal space. Countries are grouped into three categories: limited, some, and ample fiscal space, with colours aligned with the corresponding charts using red, orange and green. Red denotes below-average fiscal space ($z \leq -1$), orange indicates a position close to the euro area average ($-1 < z \leq 1$), and green reflects above-average fiscal space ($z > 1$). Source: ESM calculations based on European Commission's spring 2026 economic forecast data, Eurostat data, European Commission's spring 2026 package data and the 2024 Ageing Report

Table A8.3

Grouping of countries based on fiscal space indicators under adverse

Country	Debt to revenue	Budget balance (% GDP)	Fiscal flexibility	Interest-growth	Adverse composite
Austria	-0.30 ●	-1.36 ●	-0.67 ●	-1.05 ●	-0.84 ●
Belgium	-1.55 ●	-1.86 ●	-0.25 ●	-1.43 ●	-1.27 ●
Bulgaria	1.01 ●	-1.04 ●	-2.07 ●	-2.06 ●	-1.04 ●
Croatia	0.65 ●	-0.66 ●	-0.02 ●	-0.60 ●	-0.16 ●
Cyprus	0.99 ●	1.79 ●	-0.01 ●	-0.27 ●	0.62 ●
Estonia	1.41 ●	-0.67 ●	-0.26 ●	-3.00 ●	-0.63 ●
Finland	-0.47 ●	-1.09 ●	-1.34 ●	-1.31 ●	-1.05 ●
France	-1.62 ●	-2.16 ●	-0.94 ●	-1.69 ●	-1.60 ●
Germany	0.00 ●	-1.16 ●	1.58 ●	-1.16 ●	-0.18 ●
Greece	-2.04 ●	0.74 ●	-0.70 ●	-1.69 ●	-0.92 ●
Ireland	0.28 ●	1.17 ●	1.53 ●	1.48 ●	1.12 ●
Italy	-2.58 ●	-1.05 ●	-1.52 ●	-2.88 ●	-2.01 ●
Latvia	0.44 ●	-1.06 ●	-0.77 ●	-3.00 ●	-1.10 ●
Lithuania	0.19 ●	-1.20 ●	-0.95 ●	-2.31 ●	-1.07 ●
Luxembourg	1.66 ●	0.40 ●	0.56 ●	-0.53 ●	0.52 ●
Malta	0.32 ●	-0.45 ●	0.29 ●	1.31 ●	0.37 ●
Netherlands	0.78 ●	0.05 ●	2.82 ●	-0.84 ●	0.70 ●
Portugal	-0.95 ●	0.20 ●	-1.42 ●	-0.87 ●	-0.76 ●
Slovakia	-0.17 ●	-1.93 ●	-0.55 ●	-1.83 ●	-1.12 ●
Slovenia	0.05 ●	-1.46 ●	-0.94 ●	-0.65 ●	-0.75 ●
Spain	-1.54 ●	-0.73 ●	-1.27 ●	-1.61 ●	-1.29 ●

Notes: Fiscal space is measured as the simple average of four sign-adjusted, expressed as z-scores so that higher values indicate more fiscal space. Countries are grouped into three categories: limited, some, and ample fiscal space, with colours aligned with the corresponding charts using red, orange and green. Red denotes below-average fiscal space ($z \leq -1$), orange indicates a position close to the euro area average ($-1 < z \leq 1$), and green reflects above-average fiscal space ($z > 1$). Source: ESM calculations based on European Commission's spring 2026 economic forecast data, Eurostat data, European Commission's spring 2026 package data and the 2024 Ageing Report

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2. Annex to Chapter 2

Online annexes to [Chapter 2](#) of the Euro Area Stability Watch document the data, sample coverage, variable definitions, and empirical and modelling approaches used in the chapter. They mirror the structure of the main text, detailing the firm-level analysis of the defence sector, spillover mechanisms, and the macroeconomic model and simulations, and include complementary extensions and robustness exercises.

A9 Micro-level analysis of defence

This Annex details the defence firm-level analysis and spillovers discussed in [Chapter 2](#). It describes the data sources and construction of the defence-firm sample, outlines the empirical methodology, and provides further evidence to supplement the chapter's findings.

A9.1 Mapping the euro area defence ecosystem

Despite its economic and strategic relevance, firm-level analysis of the European defence sector remains scarce. With a turnover of about €150 billion in 2024, half a million direct jobs, and over 2,500 small and medium-sized enterprises (SMEs) active in defence-related supply chains across the European Union (EU), the defence industry is a major economic sector marked by a high concentration of capital, skills, and technology (Aerospace, Security and Defence Industries Association of Europe (ASD), 2025; European Commission, 2024).¹⁰ Yet the literature on the sector remains limited, largely theoretical, and only a handful of studies use granular data.¹¹ Hence, we still lack a comprehensive empirical understanding of the salient characteristics, composition, and structure of the European defence sector, a gap partly due to the difficulty of identifying defence firms and the scarcity of accurate, often sensitive, data. This study aims to help fill that gap by providing a more granular perspective on the sector.

For large defence players, more granular firm-level information is available. While several European companies regularly appear in the worldwide Defence News Top100, their overall presence remains limited – with only 18 featured in 2024, representing about 13.1% of global defence-related revenues. For these groups, defence activities often account for only part of their turnover, with defence sales averaging roughly 60% of revenues. This underscores the dual nature of many defence firms, combining defence and civilian operations and complicating efforts to map the sector.¹²

Alternative approaches, such as industry-code mapping or procurement-based identification, do not provide a comprehensive view of the defence sector. Only a few four-digit industry codes, known as NACE codes (corresponding to the French version of statistic nomenclature of European economic activities), identify arms manufacturers (NACE 2051, 2540, 3040), but even these often capture non-defence activities. This

approach also overlooks much of the ecosystem across other manufacturing segments and services. Procurement data offers another option but has limits: it does not isolate defence-specific spending and minimum contract-value thresholds in a monopsonistic, prime-dominated procurement market bias coverage towards major contractors, limiting visibility over the broader defence supply chain.

To partially address these shortcomings, this study draws on membership lists from national professional associations to identify firms active in the sector. Using these primary sources, a comprehensive firm-level dataset of defence-sector companies is compiled for France, Germany, Italy, and Spain. These representative groups span a wide range of industrial, research, service, and advisory activities supporting military and security actors across land, air, aerospace, and naval domains.

Their members represent an important part of the industrial and technological backbone of the defence ecosystem. Membership is based on firms' sectoral activity and strategic relevance for defence and security markets, requiring substantive involvement in related industrial or technological fields. Although formal procurement relationships with public defence authorities are not required, member firms generally operate directly or indirectly in markets where such contracts are central. The associations bring together major prime contractors and parts of their supply chain, ranging from Tier-1 suppliers to smaller actors. This approach therefore captures a broader ecosystem, spanning large groups, mid-caps, SMEs, and start-ups engaged in, though not exclusively dedicated to, defence activities.¹³

A key contribution of this work is linking the identified defence companies to the Orbis firm-level database to obtain financial and other firm-level information. This linkage relies on a fuzzy matching algorithm with strict thresholds, complemented by extensive manual verification to ensure high-quality matches.¹⁴ Following this procedure, 2,386 unique firms operating within the defence ecosystem are successfully matched to a corresponding company identifier in Orbis. Of these, 1,781 firms have at least partial balance-sheet data. Their country distribution is as follows: France (791), Spain (369), Italy (354), and Germany (267).¹⁵

A9.2 Overview of the defence sector

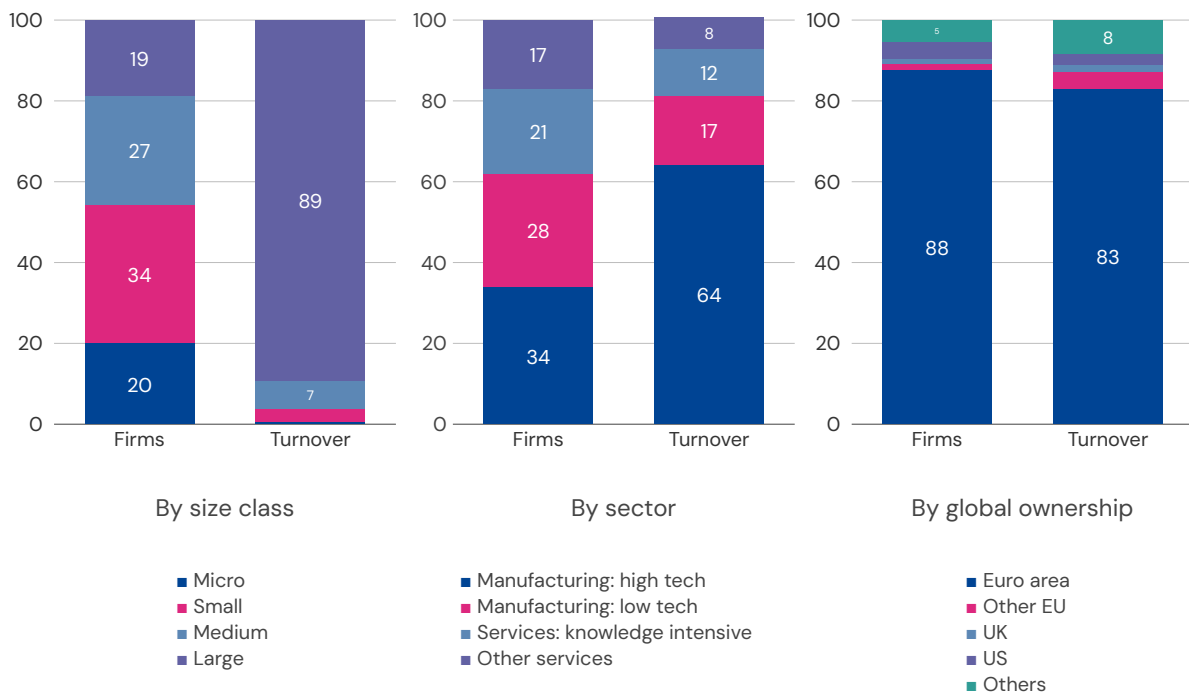
The sample of defence firms spans all size classes, though turnover is concentrated in large firms (Figure A9.1 left). Sectorally, Figure A9.2 shows that defence-related firms operate well beyond traditional arms production, combining advanced and dual-use manufacturing with a broad base of specialised services. High-tech manufacturing and knowledge-intensive services together account for around three-quarters of total turnover, underscoring the sector's technologically advanced profile (Figure A9.1, middle). Ultimate ownership is predominantly euro area based (Figure A9.1, right). Foreign ownership remains limited (12% to 17%), though still higher than in the United States (US), where entry barriers lead to overwhelmingly domestic ownership.¹⁶ Finally, supply-chain patterns show that defence-intensive sectors rely mainly on domestic suppliers, supplemented by a non-negligible share from other euro area countries

(Figure A9.3). Cross-border integration remains modest, but intra-euro area sourcing exceeds the economy-wide average. At the same time, reliance on the rest of the world is somewhat higher than in all sectors combined, reflecting the global sourcing of high-tech components.

Figure A9.1

Overview of firms operating in the defence sector

(shares of defence firms and turnover by size, sector, and global ownership, in %)



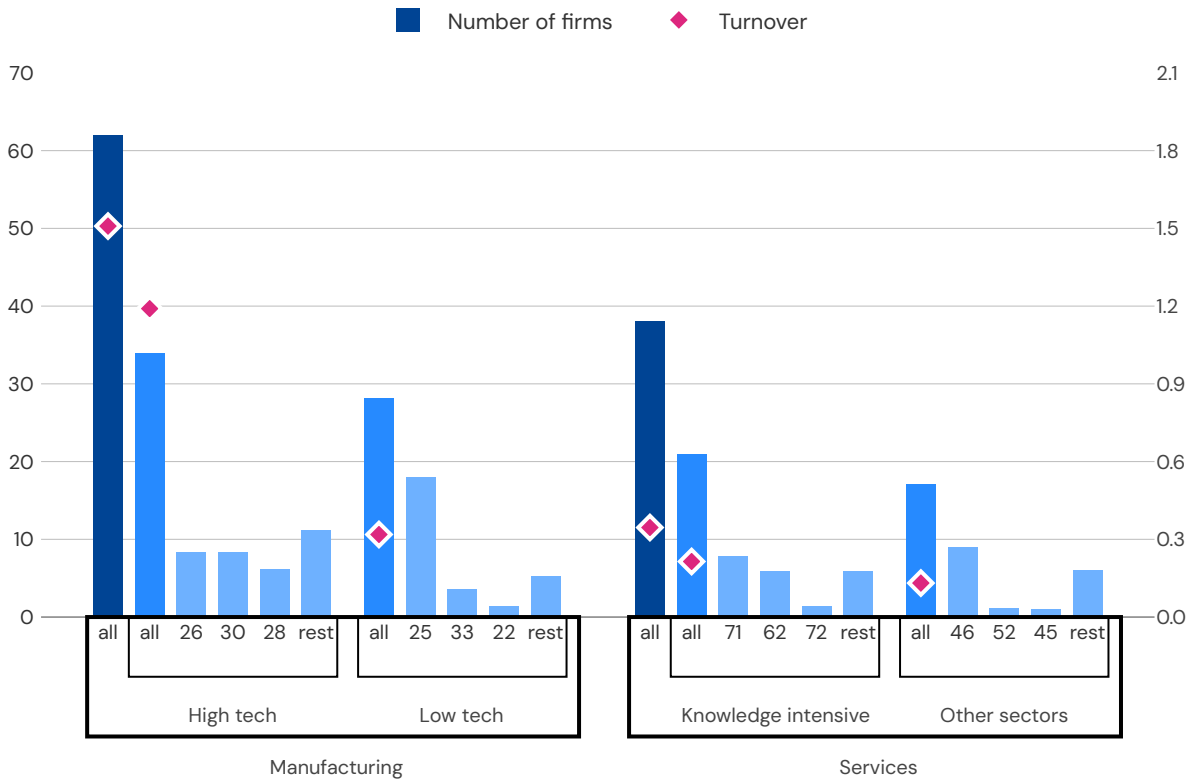
Notes: Based on the identified sample of defence firms in the four euro area countries, comprising 1,379 firms with non-missing operating revenue (2019–2022 average). The division of sectors into technology- and knowledge-intensive categories follows the Organisation for Economic Co-operation and Development classification at the NACE two-digit level.

Source: ESM calculations

Figure A9.2

Defence ecosystem: a sectoral footprint extending beyond arms

(left axis: count in % of defence firms; right axis: in % of all firms' turnover)



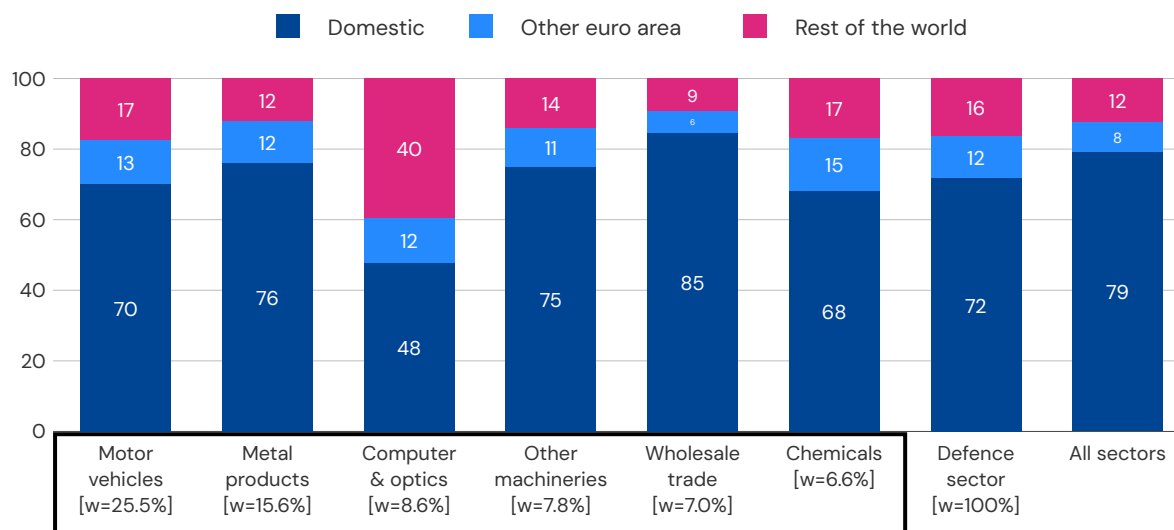
Notes: Based on the sample of defence firms in four euro area countries, comprising 1,379 firms with non-missing operating revenue (2019–2022 average). The x-axis shows the decomposition into the top three NACE two-digit sectors, with labels indicating key subsectors. The right-hand scale reports defence firms' operating-revenue share out of total turnover across all firms in the sample, computed only for sectors where defence firms operate. For manufacturing, high-tech activities are broken down into NACE 26 (computer, electronic, and optical products – 2611, 2630, 2651), NACE 30 (aircraft – 3030; military vehicles – 3040), NACE 28 (machinery and equipment not elsewhere classified. – 2829, 2899), and a residual category covering explosives (2051), electrical equipment (27), and motor vehicles (29). Low-tech manufacturing includes NACE 25 (weapons and ammunition – 2540; machining – 2562; metalworking – 2511, 2550), NACE 33 (repair of aircraft and ships – 3316, 3315), NACE 22 (rubber and plastic products), and a residual category comprising basic metals (24), textiles (13), and other manufacturing (32). For services, knowledge-intensive activities comprise NACE 71 (engineering and technical services – 7112, 7120), NACE 62 (computer programming and consultancy – 6201, 6202, 6209), NACE 72 (scientific R&D), and a residual category covering advisory and consulting (7490, 7022) and software (5829). Less knowledge-intensive services include NACE 46 (wholesale of machinery and information-and-technology equipment – 4669, 4652), NACE 52 (transport support services – 5229), NACE 45 (sale of motor vehicles – 4519), and a residual category encompassing business support (8299), freight (4941), and specialised construction (23).

Source: ESM calculations

Figure A9.3

Defence sector's heavy reliance on euro area supply chains

(in % of total intermediate inputs)



Notes: The "all sectors" aggregate pools all output/downstream sectors across the four euro area economies and sums their intermediate inputs by source country (i.e. across all input/upstream sectors). For the defence sector aggregate, each downstream sector is weighted by the share of total material costs incurred by defence firms operating in that sector. The resulting weighted average is then shown for the defence sector as a whole and broken down into selected NACE two-digit sectors, with sector weights ("w") displayed under the labels.

Source: ESM calculations based on Organisation for Economic Co-operation and Development inter-country input-output tables (ICIO, 2022)

A9.3 Firm-level dataset

The analysis relies on the ESM's curated firm-level dataset, built from the Moody's Analytics Orbis Historical database. The sample comprises an unbalanced firm-level panel for four euro area countries (France, Germany, Italy, and Spain) over 2006–2022, with more than 1.2 million firms in manufacturing and services and 9.6 million firm-year observations in its largest version.¹⁷ To address irregularities in the raw data and build a nationally representative dataset, an extensive data compilation and variables construction process is applied, following the guidelines of Kalemli-Özcan et al. (2015, 2024), and Lauwers (2022), among others.

A9.4 The defence premium: distinct characteristics of defence firms

Building on the mapping of the defence sector, this study examines whether defence firms systematically differ from others across measurable dimensions.¹⁸ In particular, it investigates the existence of a “defence premium”, analogous to the “exporter premium” in the trade literature (e.g. De Loecker, 2007) or the productivity premium of digital-intensive firms.

A common approach to quantify this premium is to regress the log of firm-level characteristics on an indicator for defence firms, conditional on country-sector-year fixed effects and, in some specifications, firm-level controls. Formally, the following model is estimated, drawing on Bernard and Jensen (1995) and others (e.g. De Loecker, 2007; Bussolo et al., 2022):

$$y_{isc,t} = \beta DEF_{isc} + X_{isc,t-1}\Gamma + \alpha_{sc,t} + \varepsilon_{isc,t}$$

where $y_{isc,t}$ is the characteristic of firm i in sector s , country c , and year t . DEF_{isc} is a time-invariant dummy equal to one for defence firms. $X_{isc,t-1}$ includes a dummy for young firms, an indicator for whether balance sheet data is reported on a consolidated basis, and, in some specifications, lagged firm size $\alpha_{sc,t}$ denotes country-two-digit-sector-year fixed effects.

The coefficient of interest β represents the ceteris paribus average percentage difference in the selected firm-level indicator between defence and non-defence firms, conditional on the controls included in $X_{isc,t-1}$.¹⁹ Country-sector-year fixed effects ensure that firms are compared within the same country and two-digit industry in a given year, thereby accounting for common shocks along those dimensions. Standard errors are clustered at the firm level because the defence dummy is time-invariant while the dependent variable varies over time.

Table A9.1

Defence premium: systematic differences in firm characteristics

Setting Firm characteristics	All firms			By size classes			
	Uncond. (1)	Firm size (5 classes) (2)	Micro (3)	Small (4)	Medium (5)	Large (6)	Mega (7)
Employment	255.9***						
Sales per worker	22.1***	13.8***	26.7***	17.7***	6.0*	9.3**	41.4***
Average wage	22.5***	14.7***	14.3***	16.2***	10.9***	15.0***	46.4***
Fixed assets per worker	72.1***	39.2***	57.5***	45.1***	27.4***	38.5***	33.4
Fixed int. assets per worker	77.9***	54.0***	31.5*	55.2***	67.2***	45.1***	45.4
Value added per worker	27.4***	19.7***	28.6***	23.3***	15.5***	13.6***	41.3***
Value added per employee cost	3.6***	4.5***	14.8***	6.2***	3.9*	-1	-2.4
Revenue TFP	45.0***	6.3***	29.5***	15.4***	0.7	-6.1**	-14.5
Revenue TFP (markup adjusted)	44.8***	5.6***	26.1***	13.1***	1.9	-10.2***	-16.1
MRPK (markup adjusted)	-23.3***	-12.6***	-12.3	-13.6***	-6.9	-22.1***	11.3
Return on assets	6.1	14.3***	38.0***	18.8***	14.6**	-7	8.2
Material costs per worker	15.1***	7.9**	26.5***	12.8**	-3.6	7.4	9.8
Net investment per worker	40.1***	37.4***	74.7***	51.6***	15.9**	30.4***	59.1**
Net intangible investment per worker	42.3***	55.8***	46.2**	75.5***	52.6***	38.5***	55
Leverage ratio (total debt/total assets)	-1.7**	-1.8**	-5.3**	-6.7***	0.9	3.0*	13.0***

Notes: This table reports a set of regressions (Eq. 1) in which the dependent variable is one of the firm characteristics listed in the rows. All regressions include a dummy variable equal to one for defence firms as well as country-two-digit-sector-year fixed effects. Column 1 reports results from an unconditional specification. Column 2 controls for firm size using a categorical variable to allow for non-linearities. Results are robust to using the number of employees in continuous form. Columns 3 to 7 report specifications in which the defence firm dummy is interacted with firm size classes; reported coefficients correspond to total effects for each size category. All specifications excluding Column 1 additionally control for a dummy indicating consolidated accounts and for a dummy for young firms (less than six years of age). All monetary variables are deflated using the appropriate country-industry deflator. The number of observations varies across dependent variables. For instance, the revenue TFP regressions include roughly 7.6 million observations, covering more than 1.1 million non-defence firms and 1,381 defence firms. ***, **, and *prese rent 1%, 5%, and 10% levels of significance, respectively.

As a first step, Eq. (1) is estimated without controlling for firm size, as reported in column 1 of Table A9.1. Compared with non-defence firms operating in the same industries, defence firms are on average larger, generate higher sales, and pay higher wages.²⁰ They also invest more in fixed assets and exhibit substantially greater capital intensity, consistent with the technology- and equipment-intensive nature of many defence activities. This higher capital intensity partly explains their superior labour productivity – about 27% above industry peers – as additional investment in machinery and technology allows each worker to produce more output. This advantage narrows once higher wages are considered. Moreover, their larger capital accumulation is subject to diminishing returns and results in a lower marginal revenue product of capital (MRPK),

as expected in capital-intensive operations. Despite the lower MRPK, defence firms maintain higher total factor productivity (TFP), including its markup-corrected variant (following De Loecker and Warzynski, 2012), reflecting more efficient input use, stronger technological and organisational efficiency, and the sector's research and development (R&D) intensity.

Overall, defence firms display characteristics often associated with 'frontier' or high-performing firms, such as exporters or information and communication technology-intensive companies. Although these differences appear sizeable, they may partly reflect the larger scale of defence firms, as productivity generally rises with firm size. Accounting for size (column 2) narrows several differences, but the patterns remain: defence firms still show higher sales, wages, investment, capital intensity, and labour productivity, and a smaller yet statistically significant TFP premium persists.

Examining heterogeneity across firm types provides further insights (columns 3–7). Higher wages, capital intensity, sales, and labour productivity are common across defence firms of all sizes relative to non-defence peers. The premium is strongest among smaller specialised defence firms that display on average higher productivity and investment intensity than other SMEs. By contrast, larger defence firms do not show such TFP premia relative to other large companies; they benefit from market position but may face diminishing returns (as reflected in their lower MRPK) and weaker competitive pressures in concentrated procurement markets.

A9.5 Productivity spillovers to other firms: a micro perspective

Increased defence spending directly benefits arms producing and military services firms, a dynamic clearly reflected in the sector's sharp stock market revaluation since 2022. But the impact can extend well beyond final-assembly firms and generate important supply-chain effects across multiple sectors. The defence supply chain is extensive, spanning thousands of firms serving both commercial and military markets.²¹ In addition to raising demand for intermediate goods, defence outlays can generate productivity gains among suppliers by enabling economies of scale, improving the utilisation of existing capital, and imposing higher technological and quality standards that foster more efficient and innovative production processes. At the same time, a rapid build-up can create crowding-out pressures by bidding up input costs and tightening scarce skilled labour in adjacent sectors. Knowledge diffusion could generate positive spillovers but may be limited by the sector's sensitive nature and the dominance of a few prime contractors. Overall, the net effect remains ambiguous.

This motivates a preliminary empirical analysis using firm-level data: do increases in defence-firm investment generally translate into productivity gains for the broader economy? ²²

Horizontal and vertical exposures to defence–firm investment

This study builds on the rich micro-level literature on foreign direct investment spillovers, which finds that the presence of multinationals can affect domestic firms' productivity through horizontal (within-industry) and vertical (supply-chain) linkages (e.g. Javorcik, 2004; Fons-Rosen et al., 2017). In a similar spirit, it examines whether higher investment by defence firms – typically capital- and R&D-intensive and embedded in multi-tier supply chains – affects the productivity of non-defence firms in related sectors. Two complementary measures are constructed to capture non-defence firms' exposure to increases in defence-firm investment intensity:

$$DefInv_{sc,t-1}^H \text{ and } DefInv_{sc,t-1}^V.$$

Both measures rely on a common underlying variable, $DefInv_{sc,t-1}$, which captures the investment intensity of defence firms at the country-sector-year level. At the firm level, investment intensity is defined as the annual change in total fixed assets (tangible plus intangible) scaled by lagged total assets. This net investment (i.e. net of depreciation) reflects capital expenditures beyond replacement needs, better capturing expansions in productive capacity while avoiding reliance on noisy depreciation data. Negative firm-level values are censored at zero to focus on long-term asset accumulation. Firm-level intensities are then aggregated to the country-sector-year level using lagged total assets as weights, giving greater emphasis to large defence firms more exposed to procurement programmes. Separate regressions further distinguish tangible investment (e.g. buildings, machinery) from intangible investment (e.g. R&D, formation costs, and other long-term investments).

From the perspective of a non-defence firm i operating in sector s and country c , the first measure $DefInv_{sc,t-1}^H \equiv DefInv_{sc,t-1}$, captures its horizontal exposure to the investment intensity of defence firms operating in the same country-sector. This variable proxies for potential intra-industry spillovers, such as scale effects, learning, technology dissemination, or competitive pressure arising when defence firms expand investment within the same sector.

The second measure, $DefInv_{sc,t-1}^V$, captures the vertical exposure of upstream non-defence firms to investment by defence firms in other sectors. Such supply-chain spillovers enter through an input-output weighted aggregation: $DefInv_{sc,t-1}^V = \sum_{k \neq s} \omega_{skc} DefInv_{kc,t-1}$, where the input-output weights ω_{skc} denote the time-invariant share of output from sector s in country c that is sold to sector k across euro area countries, averaged over time. This measure captures the country-sector-year exposure of upstream non-defence 'suppliers' in sector s to the investment intensity of defence firms in downstream sectors $k \neq s$. In essence, $DefInv_{sc,t-1}^V$ reflects how defence-driven investment expansions in downstream industries propagate back to upstream civilian firms through established input-output linkages.

Following prior work (e.g. Hall et al., 2012), both exposure measures are log-transformed to reduce right-skewness and emphasise proportional changes over absolute ones,

thereby facilitating comparisons across sectors and countries of different scale.

Empirical approach

The empirical approach addresses two questions sequentially. First, it assesses horizontal spillovers by testing whether non-defence firms in the same two-digit sector and country as defence firms experience changes in productivity when defence-firm investment intensity rises. Second, it analyses vertical spillovers, asking whether defence-firm investment in downstream sectors propagates to the productivity of non-defence firms in upstream sectors. To test these channels, the framework relates non-defence firms' revenue-based total factor productivity (TFPR) to the two lagged exposure measures, $DefInv_{sc,t-1}^H$ and $DefInv_{sc,t-1}^V$, using the same specification and varying only the main regressor. Excluding identified defence firms from the sample, the following specification is estimated separately for each measure:

$$\log(TFPR_{isc,t}) = \beta^m DefInv_{sc,t-1}^m + X_{isc,t-1}\Gamma + \alpha_i + \alpha_{s,t} + \alpha_{c,t} + \varepsilon_{isc,t}, \quad \forall m \in \{H, V\} \quad (2)$$

TFPR refers to total revenue factor productivity of firm i in sector s , country c , and year t .²³ The vector $X_{isc,t-1}$ includes common lagged firm-level controls: size (log of employees), age (in log), return on assets (ROA, net income over total assets), and the capital-to-labour ratio (K/L, fixed assets per worker). Results are robust to alternative control sets and to their sequential inclusion or omission. Firm fixed effects α_i absorb time-invariant firm characteristics, while sector-year $\alpha_{s,t}$ and country-year $\alpha_{c,t}$ fixed effects absorb shocks common to all firms within a sector or within a country in a given year, such as euro area sectoral demand trends, input-price changes, or macroeconomic fluctuations. Eq. (2) is estimated by ordinary least squares, and the standard errors are clustered at the two-digit sector-year level.²⁴

The coefficient of interest β^m captures (in this log-log specification) the elasticity of non-defence firms' TFPR with respect to lagged defence-investment intensity – either in the same country-sector when $m = H$, or in downstream sectors when $m = V$. Identification exploits country-sector-year deviations in lagged defence-investment intensity from shocks common to sector-years and to country-years.²⁵ These deviations capture each country-sector's within-year relative position – specifically, whether it lies above or below its sector-year and country-year benchmarks. With firm fixed effects, is identified from within-firm variation over time in exposure to these country-sector differences. Identification thus relies on comparing a given non-defence firm's TFPR across years in which its country-sector's lagged defence-investment intensity exposure takes a relatively higher versus lower position, after removing sector-year and country-year components.

Horizontal spillovers

Starting with horizontal spillovers, [Table A9.2](#) shows no statistically significant average effect of defence-firm investment intensity on the productivity of non-defence firms operating in the same two-digit sector and country (column 1). This result also holds when restricting the sample to sectors with a non-negligible defence presence (columns 2–3).²⁶

Distinguishing intangible from tangible investment (columns 4–5), the results provide some evidence of positive horizontal spillovers for intangible intensity, while tangible shows none. Yet the intangible coefficient is economically small and only marginally significant once weaker linkages are filtered out, suggesting that knowledge-based spillovers from defence-funded intangibles are modest or may require additional complementarities to materialise.

Table A9.2

Productivity spillovers to non-defence firms: horizontal linkages

Dependent variable (in log)	TFPR total	TFPR tangible	TFPR intangible	TFPR total	TFPR total	TFPR total	TFPR total	TFPR intangible
Type of investment	total	tangible	intangible	total	total	total	total	intangible
Filter out small linkages	no	no	no	>p10	>p25	no	no	no
Firms' absorptive capacity	no	no	no	no	no	yes	no	no
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$DefInv_{sc,t-1}^H$	0.0002 (0.18)	-0.0002 (-0.20)	0.0018** (2.06)	0.0003 (0.21)	-0.0004 (-0.28)	0.0009 (0.59)	0.0037 (1.60)	0.0076*** (2.83)
$DefInv_{sc,t-1}^H \times D_{isc,t-1}^{TFPR}$						-0.0006 (-0.42)		
$DefInv_{sc,t-1}^H \times D_{sc,t-1}^{self-input}$							-0.0056** (-1.96)	
$DefInv_{sc,t-1}^H \times D_{sc,t-1}^{tech\ openness}$								-0.0070** (-2.46)
$D_{isc,t-1}^{TFPR}$						0.148*** (17.22)		
Size	0.059*** (13.98)	0.058*** (13.39)	0.061*** (13.41)	0.062*** (13.72)	0.049*** (15.14)	0.052*** (13.93)	0.059*** (13.96)	0.061*** (13.39)
Age	0.068*** (21.47)	0.070*** (20.88)	0.068*** (19.87)	0.070*** (21.03)	0.065*** (15.75)	0.056*** (19.54)	0.068*** (21.40)	0.068*** (19.89)
ROA	0.601*** (19.25)	0.595*** (18.24)	0.643*** (19.15)	0.610*** (18.04)	0.516*** (24.07)	0.420*** (16.89)	0.601*** (19.26)	0.643*** (19.16)
K/L	-0.009*** (-13.24)	-0.010*** (-13.33)	-0.010*** (-14.19)	-0.010*** (-13.96)	-0.010*** (-11.40)	-0.007*** (-11.37)	-0.009*** (-13.20)	-0.010*** (-14.11)
N	3586533	3511013	3149330	3106122	2259582	3586533	3586533	3149330
R ²	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Within adj. R ²	0.0484	0.0472	0.0518	0.0504	0.0417	0.0914	0.0489	0.0520

Notes: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). Details are given in the table header and the main text. Source: ESM calculations

Next, heterogeneity in spillover channels is assessed by interacting defence-investment intensity with binary indicators capturing (i) firms' absorptive capacity, (ii) sectors' reliance on their own intermediate inputs, and (iii) sectors' degree of technological openness.

The first test considers whether non-defence firms' absorptive capacity conditions horizontal spillovers by interacting the main regressor with a dummy that equals one for non-defence firms whose ex-ante TFPR exceeds the country-sector-year median. As column 6 of [Table A9.2](#) shows, the absence of average within-sector spillovers persists regardless of firms' initial productivity.

Turning to sectoral heterogeneity, horizontal spillovers hinge on a sector's reliance on its own intermediate inputs (column 7). The main regressor is interacted with a dummy for industries with above-median own-inputs use (i.e. sourced within the same sector). In low own-input sectors, defence-firm investment intensity has a positive effect on non-defence firms' TFPR, whereas in high own-input sectors the effect turns negative. In highly self-dependent sectors, upstream and downstream activities are concentrated within the same sector: defence-led expansions may induce some upgrading among suppliers but also create input bottlenecks that may crowd out other firms and ultimately yield negative spillovers.

Finally, attention turns to whether horizontal (knowledge) spillovers depend on a sector's degree of technological self-containment – its openness to external knowledge. Defence firms' intangible investment intensity is interacted with an indicator for technologically closed sectors, characterised by fewer patent-proximity links to other industries and a more specialised knowledge base. [Table A9.2](#) column 7 shows that TFPR co-moves positively with defence investment intensity in technologically open sectors, but negatively in technologically closed, self-contained sectors. This pattern is consistent with spillovers materialising when knowledge circulates more freely: openness improves absorptive capacity and access to complementary know-how, enabling defence-related intangible investment to transmit within the sector. By contrast, in highly self-contained sectors, innovation remains concentrated and protected among a few actors, which could limit diffusion beyond the defence supply chain. An intangible-led build-up may also tighten local markets for specialised engineers and niche technologies, raising input costs for non-defence peers and offsetting potential learning gains.

Vertical spillovers

Turning now to vertical spillovers, the analysis examines whether defence firms' investment in downstream sectors propagates to the productivity of non-defence firms in upstream sectors. [Table A9.3](#) presents the results. The estimates indicate positive backward vertical spillovers: the elasticity from the log-log regression in column 1 implies that a 1% increase in input-output-weighted downstream defence-investment intensity is associated with a 0.0077% increase in upstream non-defence firms' TFPR. A one-standard-deviation increase (1.18) corresponds to roughly a 0.91% rise in upstream firms' TFPR.

These spillovers, however, are concentrated among firms with higher pre-existing TFP, that is, those closer to the productivity frontier. This highlights the role of absorptive capacity in enabling firms to capture supply-chain benefits. Upstream firms already near the technological and organisational frontier are better positioned to absorb and implement downstream standards and practices, translating procurement requirements into measurable efficiency gains. By contrast, lower-productivity firms may mainly face compliance costs without realising corresponding learning benefits, yielding negligible net effects. Reassuringly, these estimated vertical spillovers strengthen when upstream supplier sectors with weak vertical linkages to downstream defence sectors are excluded (dropping country-sector cells below the 10th or 25th percentile of input-output exposure).

Vertical spillovers are driven by both tangible and intangible defence-firm investment (columns 5–6). Intangibles such as R&D relate more directly to process and quality upgrading, whereas tangible investment creates the demand pull that supports such upgrading. Tangible investment can also raise upstream productivity by fostering economies of scale and better utilisation of suppliers' existing capital.

Table A9.3

Productivity spillovers to non-defence firms: vertical linkages

Dependent variable (in log)	TFPR total	TFPR total	TFPR total	TFPR total	TFPR tangible	TFPR intangible
Type of investment	total	total	total	total	tangible	intangible
Filter out small linkages	no	no	>p10	>p25	>p10	>p10
Firms' absorptive capacity	no	yes	yes	yes	yes	yes
	(1)	(2)	(3)	(4)	(5)	(6)
$DefInv_{sc,t-1}^V$	0.0077** (2.37)	0.0048 (1.44)	0.0022 (0.59)	0.0011 (0.24)	0.0040 (1.58)	-0.0065** (-2.45)
$DefInv_{sc,t-1}^V \times D_{isc,t-1}^{TFPR}$		0.0046** (2.36)	0.0100*** (4.33)	0.0138*** (5.30)	0.0099*** (4.79)	0.0107*** (6.67)
$D_{isc,t-1}^{TFPR}$		0.183*** (14.94)	0.206*** (14.91)	0.222*** (15.21)	0.214*** (15.24)	0.229*** (18.15)
Size	0.063*** (18.64)	0.055*** (18.65)	0.053*** (17.32)	0.052*** (14.73)	0.053*** (17.29)	0.053*** (17.38)
Age	0.072*** (25.92)	0.060*** (23.13)	0.055*** (24.35)	0.053*** (21.36)	0.055*** (24.17)	0.056*** (24.38)
ROA	0.544*** (23.79)	0.372*** (19.64)	0.363*** (17.64)	0.381*** (16.22)	0.363*** (17.64)	0.363*** (17.56)
K/L	-0.007*** (-9.89)	-0.005*** (-7.94)	-0.005*** (-7.17)	-0.004*** (-5.95)	-0.005*** (-7.12)	-0.005*** (-7.17)
N	5966302	5966302	5345448	4442064	5345448	5345448
R ²	0.99	0.99	0.99	0.99	0.99	0.99
Within adj. R ²	0.0420	0.0845	0.0829	0.0842	0.0830	0.0833

Notes: * (p < 0.10), ** (p < 0.05), *** (p < 0.01). Details are given in the table header and the main text. Source: ESM calculations

So far, the outcome is revenue-based TFPR, which mixes technology and demand/price components. When TFPR is purged of estimated firm-level markups to approximate physical TFP (Table A9.4, column 2), most of the TFPR response survives, indicating that vertical spillovers operate primarily through physical productivity, not prices. Complementary regressions support this interpretation. Upstream firms exposed to downstream defence-investment display higher MRPK (column 3), that is higher returns to deployed capital, and labour productivity (column 4), gains in value added (column 5), and reductions in employment (column 7). Taken together, these patterns suggest that

defence-related demand extends beyond higher intermediate-input sales. Among more capable suppliers, increased demand and stricter technical and quality standards imposed by defence firms may contribute to higher capital utilisation and organisational upgrading, consistent with process rationalisation, targeted capital deepening, and measurable gains in physical TFP, MRPK, and labour productivity.

Table A9.4

Vertical linkages, additional dependent variables

Dependent variable (in log)	TFPR	TFPR markup adj.	MRPK	LP	Value added	markup	employees	wage
Type of investment	total	total	total	total	total	total	total	total
Filter out small linkages	>p10	>p10	>p10	>p10	>p10	>p10	>p10	>p10
Firms' absorptive capacity	yes	yes	yes	yes	yes	yes	yes	yes
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$DefInv_{sc,t-1}^V$	0.0022 (0.59)	-0.0009 (-0.27)	0.0035 (0.58)	0.0069 (1.09)	0.0057 (0.92)	0.0066* (1.96)	0.0028 (1.00)	0.0132** (2.16)
$DefInv_{sc,t-1}^V \times D_{isc,t-1}^{TFPR}$	0.0100*** (4.33)	0.0097*** (4.46)	0.0099*** (4.06)	0.0087*** (4.10)	0.0079*** (2.79)	0.0010 (0.96)	-0.0052*** (-3.31)	-0.0015 (-1.20)
N	5345448	5161393	5161393	5032057	5345448	5161393	5032057	5032057
R ²	0.99	0.99	0.92	0.88	0.97	0.87	0.95	0.83
Within adj. R ²	0.0829	0.1284	0.3745	0.0648	0.2987	0.0831	0.1885	0.0046

Notes: * (p < 0.10), ** (p < 0.05), *** (p < 0.01). Details are given in the table header and the main text. Source: ESM calculations

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A10 Model structure and simulations

This annex documents the macroeconomic model used in [Chapter 2](#), formally defines the notion of self-financing, and outlines the simulation exercises. The framework is a quarterly, medium-scale New Keynesian dynamic stochastic general equilibrium model featuring nominal rigidities, sectoral production, capital accumulation, and an explicit fiscal-monetary block. Its disaggregation into civilian and defence sectors allows for the characterisation of relative prices and defence-specific investment dynamics. This structure provides a realistic representation of the European defence industry's size and facilitates the integration of micro-level empirical evidence into the macroeconomic calibration. The model is used to analyse defence spending shocks and their transmission to aggregate demand, prices, public finances, and productivity. A key feature of the framework is its overlapping generation structure, which breaks Ricardian equivalence: households with finite planning horizons do not fully offset government borrowing with additional saving. As a result, the way defence spending is financed – whether through deficit or taxes – has real economic implications.

A10.1 Model

We study an overlapping generations economy in the tradition of the Blanchard-Yaari perpetual youth model (Yaari, 1965; Blanchard, 1985). The overlapping-generations structure introduces non-Ricardian equivalence and can be interpreted as a reduced-form representation of richer incomplete-market environments in the Heterogeneous Agent New Keynesian literature (Farhi and Werning, 2019). The overlapping generations structure closely follows Rachel and Ravn (2025), to which we refer for further details.

Building on the work of Antonova et al. (2025), we consider a stylised two-sector economy. We study the interaction between a specialised defence industry and the rest of the economy that we refer to as the civilian sector. The defence industry produces military equipment and related services for the government, which acts as a monopsonist in the demand for defence output. We consider a closed-economy setting and calibrate the military sector to match empirical evidence on the domestic absorption of defence production. Our empirical findings at the micro-level are used to discipline the spillovers from defence-related investment to aggregate productivity.

Households

Households are of two types: optimising (Ricardian) and hand-to-mouth. Ricardian households smooth consumption intertemporally and accumulate both government bonds and physical capital, while hand-to-mouth households consume their current disposable income. Each period, a new cohort of households of mass $1-q$ is born; each household has survival probability q between periods. Preferences are given by

$$U_{s,t} = \sum_{h=0}^{\infty} (\beta q)^h \left(\log c_{s,t+h} - \frac{\psi}{1+\kappa} n_{s,t+h}^{1+\kappa} \right),$$

where $U_{s,t}$ denotes expected lifetime utility of a cohort born at time $s \leq t$. The effective discount factor is $\beta q < 1$ due to survival risk. Households derive utility from consumption $c_{s,t}$ and disutility from labour supply $n_{s,t}$, with $1/\kappa$ denoting the Frisch elasticity and $\psi > 0$ a scaling parameter.

We introduce a competitive life-insurance sector. At the end of each period, households deposit their assets with an insurance intermediary, which intermediates capital and bond holdings. In the event of survival, households receive actuarially fair payouts; in the event of death, assets are redistributed within the insurance sector. Free entry implies actuarially fair pricing, so that the effective return on assets of surviving households includes a mortality premium of $1-q/q$.

Households earn labour income, capital and bond income, firm profits, lump-sum transfers, and pay taxes. The flow budget constraint is

$$\begin{aligned} P_{t,c} c_{s,t} + P_{c,t}^K K_{c,s,t} + P_{d,t}^K K_{d,s,t} + P_t^n B_{s,t}^n = \\ \sum_{i \in \{c,d\}} \left[\frac{P_{i,t}^K (1 - \delta_i(u_{i,t})) + R_{i,t}^K u_{i,t}}{q} \right] K_{i,s,t-1} + (1 - \tau_{l,t}) W_t n_{s,t} + \\ \frac{1 - \xi + \xi P_t^n}{q} B_{s,t-1}^n + P_t^n d_{s,t} - T_{s,t} + \Phi_{s,t}. \end{aligned}$$

$P_{t,c}$ is the civilian good price (numeraire), $K_{i,s,t}$ represents sectoral capital holdings, while $u_{i,t}$ is the utilisation rate, which affects both depreciation δ_i and the return on capital $R_{i,t}^K$, $B_{s,t}^n$ denotes nominal government bonds. The term $1/q$ reflects the insurance-adjusted return. $T_{s,t}$ are government transfers, while $\Phi_{s,t}$ are nominal profits from firms holding. As in (Sterk and Tenreyro, 2018) we allow for a social fund. The social fund runs a balanced budget and makes real transfers to newborn agents $d_{s,t}$ financed by taxing "old" households. This ensures that at the initial steady state the real interest rate is equal to $1/\beta$.

Aggregating over cohorts yields the behaviour of Ricardian households (Farmer et al., 2011). Aggregate consumption satisfies:

$$C_{t+1} + \rho \left(\frac{V_t}{q} - \frac{V^{SS}}{q} \right) = \beta \frac{R_t}{\Pi_{t+1}} C_t$$

Where $q = \frac{(1-q)(1-\beta q)}{q(1+rk)}$. Aggregate wealth is given by

$$V_t = \sum_{i \in (c,d)} [P_{i,t}^K (1 - o_i(u_{i,t}) + R_{i,t}^K u_{i,t}) K_{i,t-1} + (1 - \xi + \xi P_t^n) B_{t-1}^n].$$

The overlapping-generations structure implies that each period a fraction q of households dies with average wealth V_t , and is replaced by a new cohort. This generational turnover introduces a wedge in the aggregate Euler equation: aggregate consumption dynamics depend not only on the real interest rate but also on aggregate wealth. Higher wealth slows consumption growth as richer cohorts are replaced by poorer entrants. A key implication is that government bond issuance is perceived as net wealth by households, raising consumption and putting upward pressure on equilibrium interest rates. All else equal, this amplifies the crowding-out of investment compared to an infinite horizon economy.

The supply side

The supply side follows a standard New Keynesian structure with two production sectors: civilian (C) and defence (D). Final output in each sector is produced under perfect competition using differentiated intermediate goods. Capital is sector-specific, while labour is perfectly mobile across sectors. Defence production uses civilian goods as intermediate inputs, capturing supply-chain linkages.

Final goods

In each sector $S \in \{C,D\}$, final output is produced by aggregating a continuum of intermediate varieties $j \in [0,1]$:

$$Y_{S,t} = \left(\int_0^1 Y_{S,j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad \varepsilon > 1.$$

Cost minimisation implies the sectoral price index:

$$P_{S,t} = \left(\int_0^1 P_{S,j,t}^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}.$$

Final goods are allocated as follows. Civilian output is used for household consumption, the production of investment goods for civilian and defence capital – denoted $I_{CC,t}$ and $I_{DC,t}$, respectively, government consumption $G_{C,t}$, and as intermediate inputs in defence production $X_{C,t}$:

$$Y_{c,t} = C_t + I_{CC,t} + I_{DC,t} + X_{C,t} + G_{c,t}.$$

Defence output is used for government purchases of defence goods $G_{D,t}$ and for the production of investment goods in the defence sector:

$$Y_{D,t} = I_{DD,t} + G_{D,t}$$

Intermediate goods

In each sector $S \in \{C,D\}$, a continuum of monopolistically competitive firms produces differentiated varieties used in final goods production. Civilian firms produce according to

$$Y_{Cj,t} = A_C (u_{Cj,t} K_{Cj,t-1})^\alpha N_{Cj,t}^{1-\alpha}$$

while defence firms combine sector-specific production with civilian intermediate inputs:

$$Y_{Dj,t} = \left(A_D (u_{Dj,t} K_{Dj,t-1})^\alpha N_{Dj,t}^{1-\alpha} \right)^\omega X_{Cj,t}^{1-\omega}$$

Firms hire labour at wage W_t and rent capital at rate $R_{S,t}^K$. Cost minimisation implies sector-specific marginal costs $MC_{S,t}$, which are identical across firms within each sector.

Price setting

Firms face quadratic price adjustment costs à la Rotemberg (1982). Each firm chooses price $P_{Sj,t+s}$ to maximise

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\Lambda_{t+s}}{\Lambda_t} \left[P_{Sj,t+s} Y_{Sj,t+s} - MC_{S,t+s} Y_{Sj,t+s} - \frac{\kappa_P}{2} (\Pi_{Sj,t+s} - 1)^2 P_{S,t+s} Y_{S,t+s} \right],$$

subject to demand:

$$Y_{Sj,t} = \left(\frac{P_{Sj,t}}{P_{S,t}} \right)^{-\varepsilon} Y_{S,t}, \quad \varepsilon > 1.$$

In symmetric equilibrium, aggregation across firms delivers sector-specific inflation dynamics that reduce to a nonlinear Phillips-type relationship linking inflation, marginal costs, and price adjustment costs.

Capital goods and investment

Capital is produced by competitive capital producers subject to adjustment costs and accumulates according to

$$K_{S,t} = (1 - \delta_{S,t}) K_{S,t-1} + I_{S,t}.$$

Adjustment costs imply a standard investment Euler equation linking the shadow value of capital $P_{S,t}^K$ (Tobin's q) to investment dynamics:

$$P_{S,t}^K = P_{S,t}^I \left[1 - \kappa_I \left(\frac{I_{S,t}}{I_{S,t-1}} - 1 \right) - \frac{\kappa_I}{2} \left(\frac{I_{S,t}}{I_{S,t-1}} - 1 \right)^2 \right] + \beta \mathbb{E}_t \frac{\Lambda_{t+1}}{\Lambda_t} \kappa_I \left(\frac{I_{S,t+1}}{I_{S,t}} - 1 \right) \left(\frac{I_{S,t+1}}{I_{S,t}} \right) P_{S,t+1}^I.$$

Investment $I_{S,t}$ is a CES composite of civilian and defence goods:

$$I_{S,t} = \prod_{J \in C,D} I_{S,J,t}^{\lambda_{SJ}}, \quad \sum_J \lambda_{SJ} = 1.$$

Cost minimisation yields

$$P_{J,t} I_{S,J,t} = \lambda_{SJ} P_{S,t}^I I_{S,t}, \quad P_{S,t}^I = \prod_{J \in C,D} \left(\frac{P_{J,t}}{\lambda_{SJ}} \right)^{\lambda_{SJ}}.$$

We assume $\lambda_{cc}=1$ and $\lambda_{cd}=0$, so civilian investment uses only civilian goods, while defence investment uses both inputs.

Capital utilisation $u_{S,t}$ raises effective capital services but increases depreciation (Christiano et al. 2005):

$$\delta_{S,t} = \delta_{0S} + \delta_1 u_{S,t}^{1+\varphi}.$$

Labour market

Labour services are differentiated across a continuum of unions, each of which supplies a distinct type of labour and sets its own nominal wage. Competitive labour aggregators combine these differentiated labour varieties into a homogeneous aggregate labour input used by firms. Because labour types are imperfect substitutes, each union has some monopoly power in wage setting.

Unions are subject to Calvo-style nominal wage rigidities. In each period, only a fraction $1-\theta_w$ of unions can re-optimize their wage, while the remaining unions adjust wages according to past inflation. Aggregate wages dynamics satisfy

$$W_t = \left[\theta_w (W_{t-1} \Pi_{t-1}^{\gamma_w} \Pi^{1-\gamma_w})^{1-\varepsilon_w} + (1-\theta_w)(W_t^*)^{1-\varepsilon_w} \right]^{\frac{1}{1-\varepsilon_w}},$$

where W_t^* denotes the newly reset wage, ε_w is the elasticity of substitution across labour types, and γ_w governs the degree of wage indexation to past inflation. Union optimisation yields a Philips curve-type relationship for nominal wage inflation.

Spillovers from defence capital to civilian productivity

To capture productivity spillovers from defence to the civilian sector, civilian total factor productivity (TFP) is assumed to depend on the stock of defence capital. This implies that sustained increases in defence investment raise the level of productivity, without generating endogenous trend growth. Civilian TFP therefore evolves according to

$$\log A_{C,t} = \log A_C + \phi_d \left(\frac{K_{D,t-1}}{K_D} - 1 \right),$$

where K_D denotes the steady-state level of defence capital and ϕ_d measures the elasticity of civilian productivity with respect to defence capital.

This specification provides a tractable mapping between empirical estimates based on investment flows at the single firm level and a transmission mechanism based on aggregate investment. The parameter ϕ_d is calibrated using our microeconomic estimates based on firm-level data, implying that a 1% increase in defence-related investment raises civilian TFP by approximately 0.008%. A sustained expansion of the defence sector - for example, doubling defence capital - implies an increase in civilian TFP of about 0.8% under the baseline calibration.

Fiscal policy and government debt

The government purchases civilian goods $G_{C,t}$, defence goods $G_{D,t}$, and provides lump-sum transfers T_t to households. Expenditures are financed through capital and labour taxes and the issuance of long-term government debt.

The real government budget constraint (in units of civilian goods) is:

$$P_t^B b_t = \frac{(1 - \xi) + \xi P_t^B}{\Pi_t} b_{t-1} + G_{C,t} + p_{D,t} G_{D,t} + p_{D,t} \mu_{D,t}^I I_{D,t} + T_t - \mathcal{R}_t,$$

where b_t denotes real public debt, P_t^B the price of long-term bonds, and Π_t gross inflation. The parameter $\xi \in (0,1)$ governs debt duration. The relative price of defence goods is $p_{D,t} \equiv P_{D,t}/P_{C,t}$ and \mathcal{R}_t denotes total tax revenues.

The term $p_{D,t} \mu_{D,t}^I I_{D,t}$ captures government support to defence investment. By lowering the effective cost of capital through a subsidy $\mu_{D,t}^I$, this policy encourages capital deepening in the defence sector and amplifies productivity spillovers to the civilian economy.

Long-term debt gives rise to valuation effects: increases in interest rates reduce the market price of outstanding debt, generating capital losses for households and partially offsetting higher debt servicing costs for the government. Valuation effects also arise as a consequence of unexpected inflation.

Fiscal rule

Fiscal policy ensures debt sustainability through a feedback rule on lump-sum transfers:

$$T_t = T - \phi_b \log \left(\frac{b_t/Y_t}{(b/Y)^{ss}} \right) - \phi_y \log \left(\frac{Y_t}{\bar{Y}} \right) + \varepsilon_{T,t}.$$

Higher debt levels reduce transfers (increase net revenues), stabilising the debt-to-gross domestic product (GDP) ratio over time. The parameter ϕ_b measures the strength of fiscal adjustment to deviations of the debt ratio from its steady state, while ϕ_y measures the response of automatic stabilisers to fluctuations in economic activity. The coefficient T governs the degree of policy inertia. Distortionary taxes follow exogenous persistent processes and play a secondary role in fiscal adjustment in the baseline calibration.

Monetary policy

Monetary policy is conducted through a Taylor-type interest rate rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}} \right)^{\rho_R} \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi(1-\rho_R)} e^{\varepsilon_{m,t}},$$

where \bar{R} denotes the steady-state nominal interest rate, $\bar{\Pi}$ the inflation target, $\rho_R \in [0,1)$ captures interest rate smoothing, and $\phi_\pi > 1$ governs the policy response to inflation deviations from target. The term $\varepsilon_{m,t}$ represents a monetary policy shock.

A10.2 Self-financing

We define self-financing as the extent to which an increase in defence-related fiscal spending is offset by endogenous general equilibrium responses. These adjustments operate through three main channels: (i) expansions in tax bases, (ii) valuation effects on outstanding government debt, and (iii) changes in relative prices. Self-financing is evaluated holding fiscal instruments fixed, so that all adjustments arise from macroeconomic responses rather than discretionary policy.

Counterfactual fiscal policy

The government budget constraint can be expressed in a compact form as:

$$P_t^B b_t = ((1 - \xi) + \xi P_t^B) \frac{b_{t-1}}{\Pi_t} + F_t - \tilde{R}_t,$$

where $\tilde{R}_t \equiv \mathcal{R}_t - T_t$

denotes net fiscal revenues, and total fiscal expenditure is:

$$F_t \equiv G_{C,t} + p_{D,t} G_{D,t} + \mu_{I,t} p_{D,t} I_{D,t}.$$

To isolate endogenous fiscal responses, we define a counterfactual in which fiscal instruments are held fixed at their steady-state values:

$$\tau_{l,t} = \tau_l, \quad \tau_{k,t} = \tau_k, \quad T_t^* = T - \phi_y \log \left(\frac{Y_t}{\bar{Y}} \right).$$

Counterfactual net revenues are therefore given by $\tilde{R}_t^* \equiv \mathcal{R}_t(\tau_l, \tau_k; \text{tax base}) - T_t^*$.

Under this definition, \tilde{R}_t^* varies only through endogenous movements in tax bases. Let Q_t denote the stochastic discount factor. Iterating the budget constraint forward and isolating the contribution from \tilde{R}_t^* gives the present discounted value budget constraint

$$\sum_{t=0}^{\infty} Q_t \Delta F_t = \sum_{t=0}^{\infty} Q_t \Delta \tilde{R}_t^* + \sum_{t=0}^{\infty} Q_t (\Delta R_t - \Delta \tilde{R}_t^*) - V_0$$

where $V_0 \equiv (1 - \xi + \xi P_0^B) \frac{b_{-1}}{\Pi_0}$ is the initial real value of government debt.

Definition of self-financing

Let $\Delta X_t \equiv X_t - X$ denote level deviations from steady state. Taking deviations and rearranging yields:

$$\sum_{t=0}^{\infty} Q_t \Delta F_t = \sum_{t=0}^{\infty} Q_t \Delta \tilde{R}_t^* + \sum_{t=0}^{\infty} Q_t (\Delta R_t - \Delta \tilde{R}_t^*) + \sum_{t=0}^{\infty} \Delta Q_t (R_t - F_t) - \Delta V_0$$

The next to last term captures the effect of time variation in the stochastic discount factor on the present value of fiscal flows. Intuitively, changes in real interest rates reweight the entire stream of steady-state fiscal obligations and therefore affect fiscal capacity. The last term captures the time-0 valuation effect of changes in bond prices and inflation on the outstanding stock of nominal debt. The change in total fiscal expenditure ΔF_t can be further decomposed in

$$\Delta F_t = \Delta G_{C,t} + p_D \Delta G_{D,t} + p_D I_D \Delta \mu_{I,t} + X_D \Delta p_{D,t},$$

where $X_D \equiv G_D + \mu_{I,D}$. The last term captures changes in the fiscal cost of defence expenditure induced by movements in relative prices.

By defining

$$\Delta \tilde{F}_t \equiv \Delta G_{C,t} + p_D \Delta G_{D,t} + p_D I_D \Delta \mu_{I,t}$$

,we can express the self-financing ratio as the fraction of the fiscal expansion that is offset by endogenous fiscal adjustments, valuation effects, and relative price effects:

$$SF = \frac{\sum_{t=0}^{\infty} \Delta (Q_t \tilde{R}_t^*) - \Delta V_0 - \sum_{t=0}^{\infty} X_D \Delta p_{D,t}}{\sum_{t=0}^{\infty} \Delta (Q_t \tilde{F}_t)}.$$

A10.3 Calibration

The model is calibrated at quarterly frequency to a euro area aggregate composed of France, Germany, Italy, and Spain. [Table A10.1](#) reports the calibrated parameters. Preferences, technology, and nominal rigidities follow Coenen et al. (2013) and Albonico et al. (2019). The share of hand-to-mouth households and the survival probability are chosen to target an average marginal propensity to consume of 0.3, consistent with Carroll et al. (2017). Steady-state public debt is set to 95.8% of GDP, corresponding to the 2024 average, while the debt-decay parameter targets an average maturity of 7.5 years.

Government expenditure-to-GDP ratios are calibrated to weighted averages over 2002–2024, implying steady-state labour and capital tax rates of 42.6% and 16.4%, respectively; the profit tax rate is set to 30%. Fiscal adjustment is assumed to operate through lump-sum transfers, which stabilise temporary deviations of the debt-to-GDP ratio, while tax rates adjust only to permanent shifts in expenditure. The fiscal rule is calibrated to return debt to steady state within 20 years. Monetary policy parameters follow Coenen et al. (2013) and Albonico et al. (2019), with an inflation response of 1.57 and an interest-rate smoothing parameter of 0.88.

We model the defence sector as the recipient of government demand for both defence-related intermediate consumption and defence investment. The latter comprises expenditures on military equipment, ammunition, and research and development, while the former includes maintenance, repair, and other service inputs. Based on the United Nations' Classification of the Functions of Government data, steady-state defence consumption and investment are set to 0.6% and 0.3% of GDP, respectively, implying total defence demand of 0.9% of GDP. Military personnel expenditures are excluded and classified as civilian government consumption. This calibration yields a defence-sector output of about 1% of GDP, consistent with European Union (EU)-level industry turnover data.²⁷

We abstract from modelling defence exports and imports, as these are of similar magnitude and broadly offset each other in aggregate. What matters for our purposes is to match the size of the domestic military sector, as this determines the scale of spillovers and the proportional response of investment to defence demand shocks.

Table A10.1

Preferences and technology

Parameter	Description	Value	Target/Source
β	Discount factor	0.9983	Albonico et al. (2019)
κ	Inverse Frisch elasticity	2	Coenen et al. (2013)
μ	Share of hand-to-mouth households	0.25	Marginal Propensity to Consume evidence
q	Survival probability	0.935	Marginal Propensity to Consume evidence
α_c	Civilian capital share	0.30	Labour income share
α_d	Defence capital share	0.40	Labour income share
χ	Civilian-input share in defence production	0.6	Share of intermediate consumption in military expenditure
κ_I	Investment adjustment cost	5.56	Coenen et al. (2013)

Source: ESM calculations

Table A10.2

Nominal rigidities and monetary policy

Parameter	Description	Value	Target/Source
ε	Elasticity of substitution (goods)	11	10% price markup
ε_W	Elasticity of substitution (labour)	11	10% Wage Markup
θ_W	Calvo wage rigidity	0.85	Two-year wage duration
γ_W	Wage indexation	0.54	Coenen et al. (2013)
κ_P	Price adjustment cost	60.0	6–8 quarters price duration
ϕ_π	Inflation response	1.6246	Albonico et al. (2019)
ρ_R	Interest rate smoothing	0.88	Coenen et al. (2013)
Π	CPI inflation in SS	1.0051	Albonico et al. (2019)

Table A10.3

Steady-state and defence sector targets

Parameter	Description	Value	Target/Source
Π	CPI inflation in SS	1.0051	Albonico et al. (2019)
τ_l	Labour tax	0.426	Weighted average Spain, Italy, Germany, France
τ_{Π}	Corporate profit tax	0.3	Albonico et al. (2013)
τ_K	Capital tax	0.164	Weighted average Spain, Italy, Germany, France
ξ	Debt-decay parameter	0.9667	Weighted average maturity of 7.5 years
B/Y	Debt-to-GDP ratio	3.824	Weighted average debt to quarterly GDP ratio
G_c/Y	Government Civilian spending	0.231	Weighted average Spain, Italy, Germany, France
G_d/Y	Government Defence spending	0.007	Weighted average Spain, Italy, Germany, France
λ_{dc}	Civilian-input share in defence investment	0.60	European Space Agency-calibrated EU average with moderate outsourcing
ϕ_d	Civilian productivity spillover	0.008	Micro-elasticities

Source: ESM calculations

A10.4 Simulations

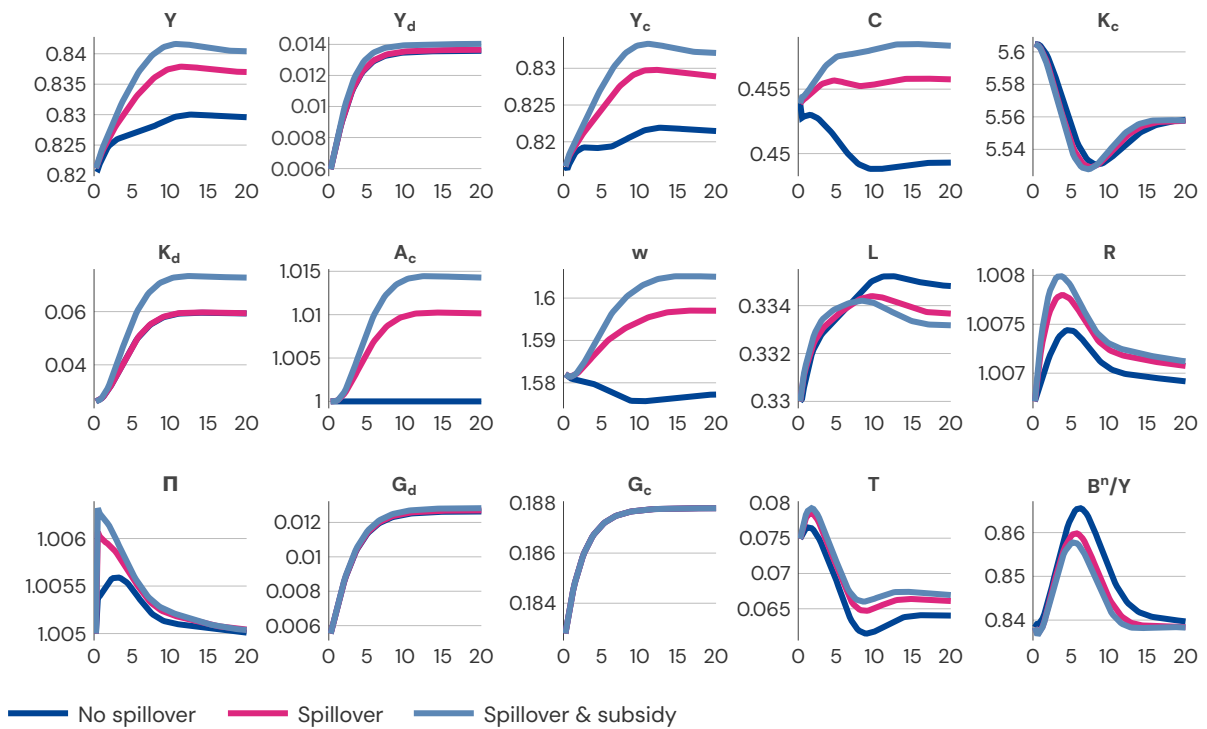
Building on the calibration in the previous section, we simulate the macroeconomic and fiscal effects of a defence build-up under the baseline non-Ricardian setting. We consider a policy experiment in which the defence budget increases gradually by 1.5 percentage points of GDP over a 10-year horizon. Of this additional spending, 70% is directed towards the domestic military industry through a combination of procurement (i.e. higher G_d) and investment subsidies, while the remaining 30% is allocated to higher public-sector wages and treated as government consumption.

We analyse three scenarios. In the first, there are no spillovers from defence spending to the domestic economy. In the second, we allow for positive spillovers, but do not introduce investment subsidies, so that the allocation of factor of production is not distorted. In the third scenario, the government implements a 20% subsidy to defence investment, corresponding to roughly 5% of the additional defence budget. The associated self-financing ratios are 25%, 44%, and 53% across the three scenarios, respectively.

Figure A10.1

Impulse response functions in a non-Ricardian setting

(level)

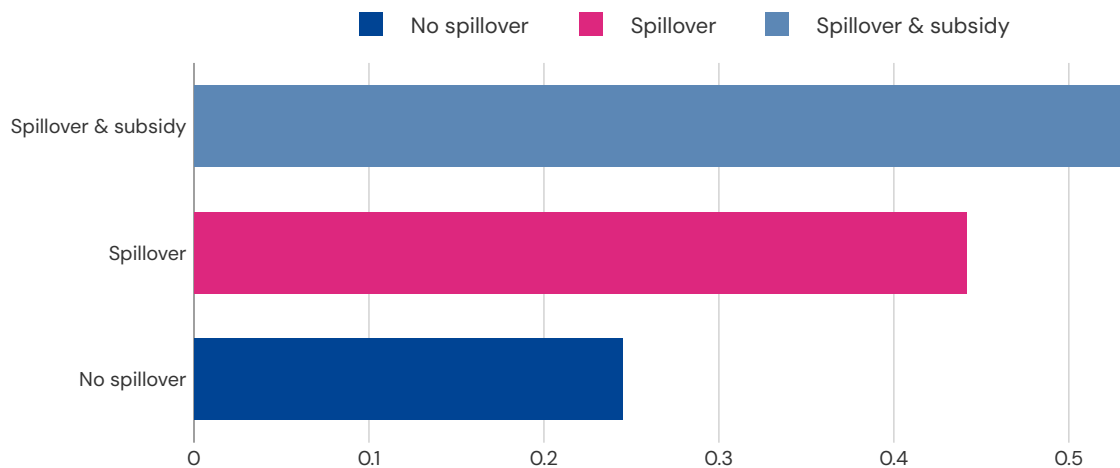


Source: ESM calculations

Figure A10.2

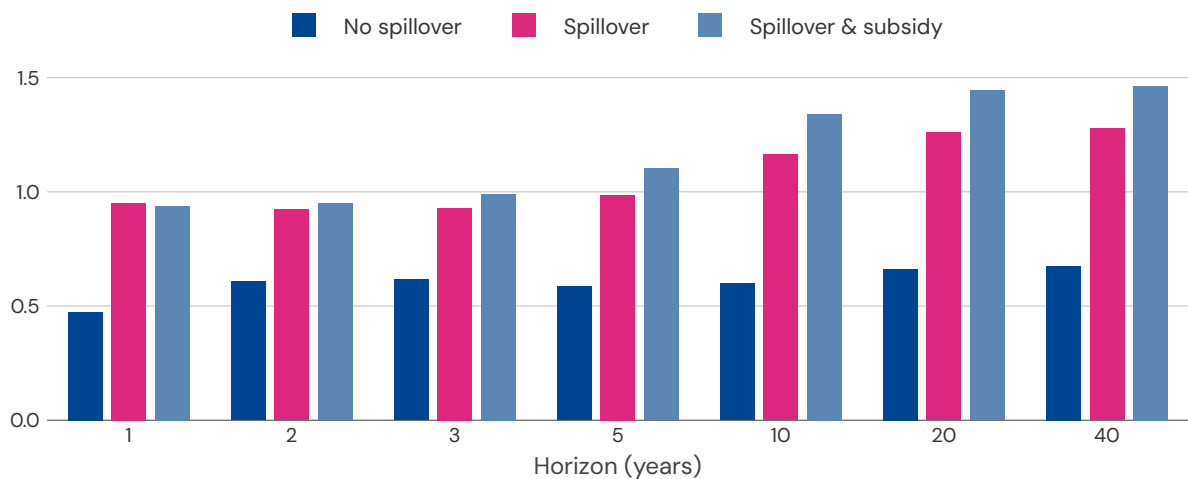
Self-financing ratio in a non-Ricardian setting

(in % of defence spending recovered)



Source: ESM calculations

Figure A10.3

Fiscal multipliers in a non-Ricardian setting

Source: ESM calculations

Short term

Turning to the transmission mechanism in a non-Ricardian setting, agents' behaviour is shaped by their holdings of financial and real assets, namely bonds and capital. On impact, real wealth declines due to a revaluation of bond portfolios: with long-term bonds, the anticipated increase in future interest rates leads to a drop in bond prices,

which depresses consumption. Over time, however, consumption recovers, supported by higher bond issuance associated with debt-financed military spending, which generates positive wealth effects.

At the same time, stronger demand – amplified by a relatively high marginal propensity to consume – puts upward pressure on interest rates. This results in a pronounced crowding-out of civilian capital accumulation as investment focus is shifted to the defence sector. Moreover, as wages need to remain sufficiently high to sustain an expansion in labour supply, the short-run increase in output is limited. As a result, the fiscal multipliers remain below one.

More broadly, the model highlights a tight link between public debt and interest rates. As debt accumulates, interest rates remain elevated, reinforcing the crowding-out of private investment. This dynamic dampens capital formation and constrains output growth in the short to medium term.

Medium to long term

Over the medium to longer-term, labour supply expands further across all three scenarios, supporting growth in both the defence and civilian sectors. The response of consumption, however, differs markedly depending on the presence of spillovers and policy design.

In the absence of spillovers, consumption declines. The expansion of the civilian sector primarily serves to accommodate the increased resource needs of the military sector. Although employment rises, the associated increase in labour income is not sufficient to fully offset the crowding-out of private consumption induced by higher government demand. As a result, the fiscal multiplier remains below 1.0 in this scenario.

The picture changes once spillovers are introduced. In this case, consumption increases modestly over time. The reason is that defence spending generates positive productivity effects in the civilian sector, effectively shifting its technology frontier outward. These gains more than compensate for the reallocation of resources towards military production, allowing both sectors to expand without a sustained compression of private consumption.

The effects become substantially stronger when the policy mix includes investment subsidies to the defence sector. By incentivising capital deepening in military production, the government effectively raises the sector's capital intensity. This acts as a form of endogenous technological improvement, which amplifies the transmission of spillovers to the civilian economy. A larger capital base in the defence sector enhances the productivity gains that diffuse to the rest of the economy, further stimulating investment and output in the civilian sector.

A10.5 Ricardian versus non-Ricardian

This section presents a robustness exercise rather than an alternative baseline. We relax the assumption of finite lifetimes and consider infinitely lived agents, nesting the Ricardian case by setting the survival rate to one. The purpose is to clarify the role of non-Ricardian behaviour in the transmission mechanism. As shown below, moving to the Ricardian setting raises both fiscal multipliers and the degree of self-financing, reinforcing rather than undermining the chapter's main findings. The baseline results in [Section A10.4](#) should therefore be interpreted as conservative.

A key implication of Ricardian behaviour is that fiscal multipliers and the degree of self-financing increase. This result stems from a more front-loaded adjustment of labour supply and consumption. In the absence of spillovers, households fully internalise that future consumption will decline. As a result, they immediately reduce consumption, increase labour supply, and raise savings. This leads to lower interest rates and real wages, which in turn stimulate investment in the civilian sector and expand overall supply.

When spillovers are present, however, households anticipate higher future consumption due to productivity gains associated with defence spending. This expectation supports demand in the short run. Stronger demand puts upward pressure on interest rates and initially crowds out civilian capital accumulation. Nevertheless, this crowding-out effect is weaker than in the non-Ricardian case. As interest rates remain relatively lower over time, complementarity between civilian and defence capital emerges, ultimately delivering a larger increase in aggregate output.

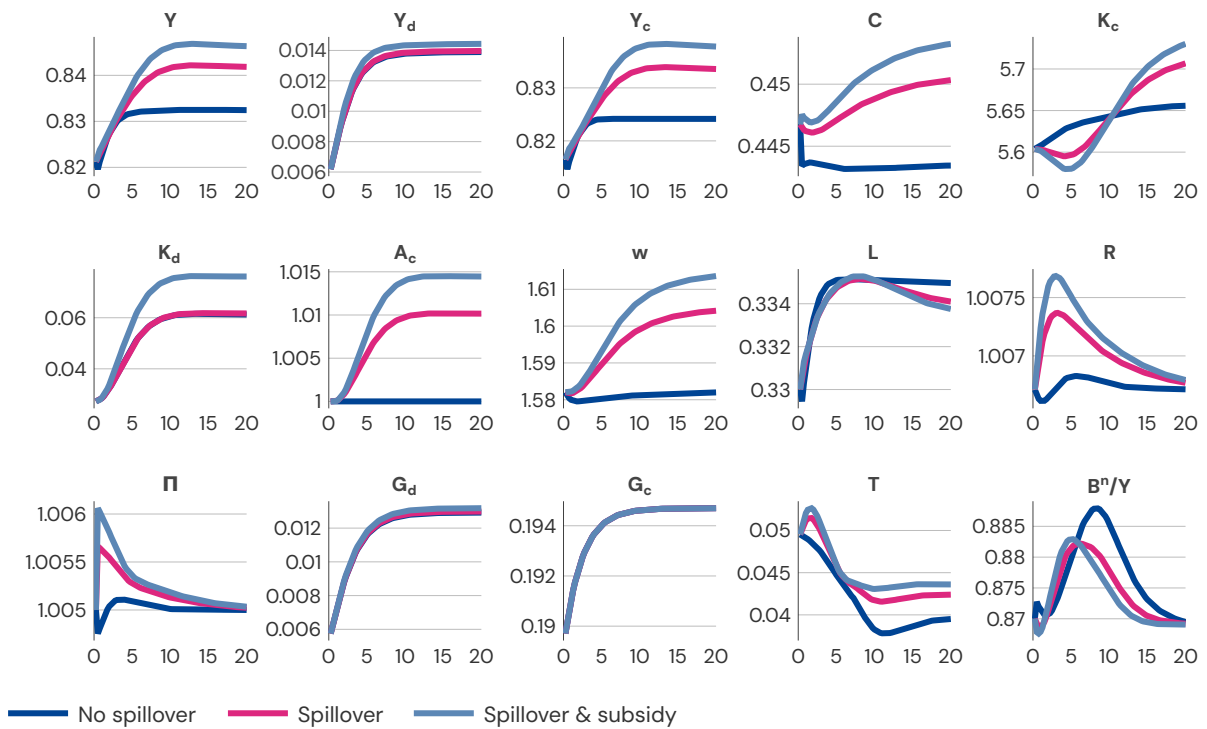
Put differently, agents anticipate that the future expansion in defence expenditure will enhance productivity. This expectation induces higher saving and investment already in the short run. Households accumulate capital in advance to benefit from the forthcoming productivity gains, so that when these gains materialise, they already hold a larger capital stock. This mechanism generates complementarity between military and civilian capital.

By contrast, when agents have finite lifetimes and behave more myopically, their marginal propensity to consume is higher. Additional saving must then be induced through higher interest rates, which crowd out civilian investment. By the time the full increase in total factor productivity materialises, agents have been unable to adjust sufficiently. In this case, military capital acts as a substitute for civilian capital, rather than a complement as in the Ricardian setting.

Figure A10.4

Impulse response functions in a Ricardian setting

(level)

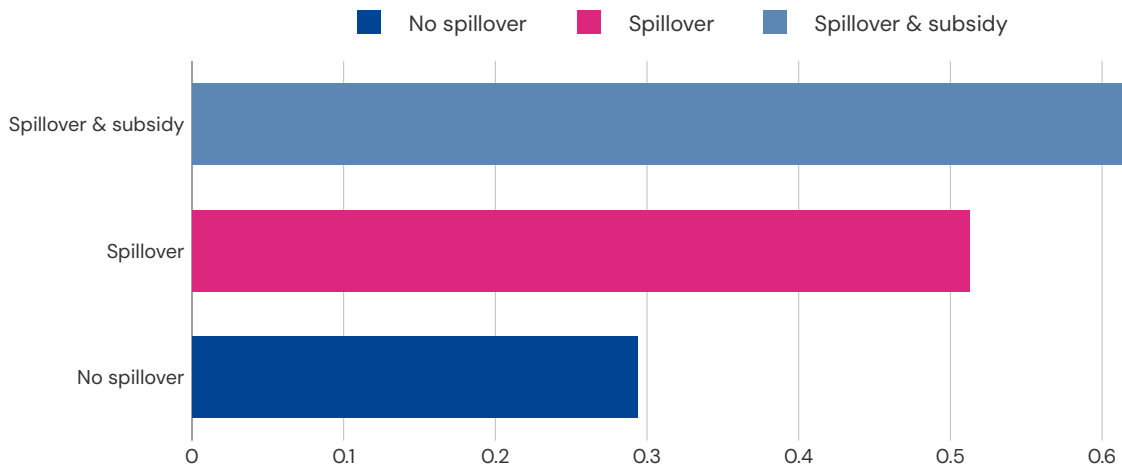


Source: ESM calculations

Figure A10.5

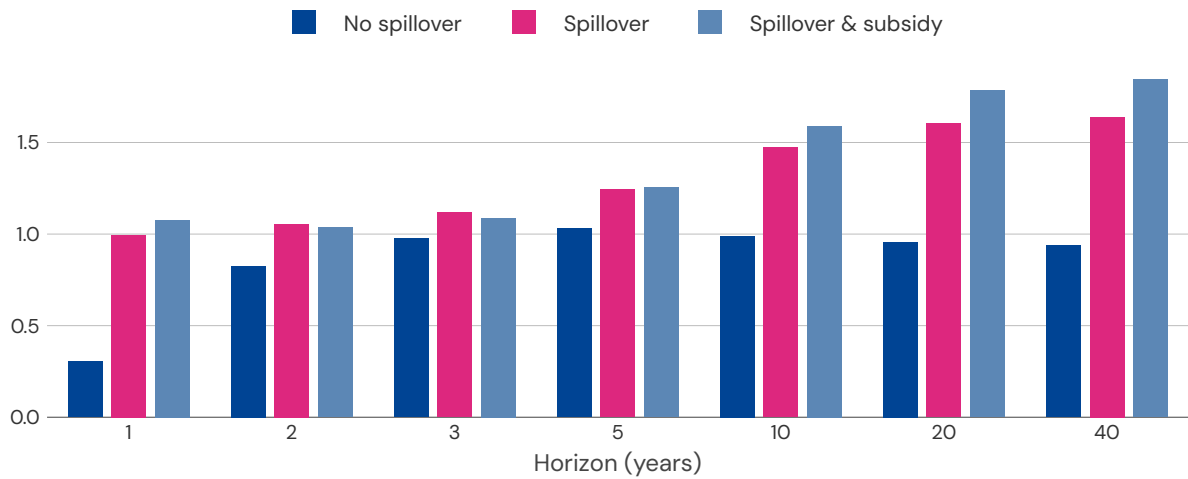
Self-financing ratio in a Ricardian setting

(in % of defence spending recovered)



Source: ESM calculations

Figure A10.6

Fiscal multipliers in a Ricardian setting

Source: ESM calculations

A10.6 References

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Footnotes

- 1 | The floor on the median precision weight prevents investor groups with very stable flows from playing too extreme a role in the weighted regression.
- 2 | For notational simplicity we drop the country-specific index j of relevant variables in the exposition of the GIV iterations.
- 3 | Germany, France, Spain, Italy, Belgium, Finland, Greece, Ireland, the Netherlands, Portugal, the United Kingdom, the US, Canada, Australia, Japan, and Switzerland.
- 4 | National accounts' variables (GDP and its components, savings, and income) enter as three-period percentage changes (quarter-on-quarter growth rates) with interpolation. Price indices (consumer price index and producer price index), trade, equity indices, and exchange rates enter as month-on-month log differences. Interest rates and sovereign spreads enter in first differences. Oil and gas prices and purchasing managers' indices enter in log levels. Harmonised index of consumer prices measures enters as year-on-year percentage changes. All panel variables are standardised to zero mean and unit variance prior to factor extraction.
- 5 | The excess bond premium is defined as the component of corporate bond spreads not directly attributable to the expected default risks, as argued in Gilchrist and Zakrajsek (2012). It is a measure of investor sentiment or risk appetite in the corporate bond market.
- 6 | To improve the estimation precision of the long-term dynamics we use the Area Wide Model database from the Euro Area Business Cycle Network.
- 7 | The closure of the output gap is country specific and driven by a model-based quantification of the adverse scenario. Nevertheless, it is assumed to close by $T+10$ at the latest.
- 8 | To limit the influence of extreme observations, the reference distribution is winsorised, meaning that values below the 5th percentile and above the 95th percentile are capped before computing the mean and standard deviation; these baseline parameters are then kept fixed across scenarios.
- 9 | Values at least one standard deviation below the mean ($z \leq -1$) are classified as weaker fiscal space (red), values within one standard deviation of the mean ($-1 < z \leq 1$) as average fiscal space (orange), and values above one standard deviation ($z > 1$) as stronger fiscal space (green).
- 10 | The size of the defence industry is difficult to estimate. Figures from the ASD association cover 20 EU countries, excluding the United Kingdom (UK), Norway, and Turkey.
- 11 | See e.g. Callado-Muñoz et al., (2022); Vaze et al., (2017); and Giacomello and Preka, (2023).

- 12 | SIPRI Top 100 Arms-Producing and Military Services Companies offers comparable figures.
- 13 | Additional sources complement the national association lists. For Germany, further coverage comes from the Kiel Military Procurement Tracker (Wolff et al., 2025). The sample also includes firms classified under NACE codes 3040, 3011, and 8422, with non-defence entities excluded. Firms listed as members of ASD – the European aerospace, security, and defence industry body – are added when not already captured, though this source is less extensively curated (e.g. some firms have since merged or dissolved).
- 14 | Several sanity checks and refinements were applied. Among other procedures: i) Industry codes, trade descriptions, and firms' websites were used to resolve some borderline and unmatched cases. ii) The largest defence players in each country were manually checked for correct identification. iii) Firms primarily active in non-defence areas – including telecommunications, retail, logistics, investment, and other general services – or with predominantly civilian aviation business were removed. iv) For diversified groups (e.g. Airbus), only defence-focused subsidiaries reporting unconsolidated accounts were retained; for Germany, where such accounts are seldom available, consolidated group data are used, alongside qualitative assessments of whether a group derives sufficient activity from defence. v) Firms classified as holdings were reassigned to more relevant NACE codes reflecting their main activities.
- 15 | After curation, the 1,781 defence firms with financial data comprise 208 firms from the national association lists of AIAD/AIPAS (Italy), 172 from BDSV/BDLI (Germany), 456 from GICAT/GIFAS (France), 257 from Spain's Ministry of Defence, and 303 from ASD; 280 firms were identified via industry codes 3040, 3011, and 8422 (after curation), and 105 added through manual verification.
- 16 | While not directly comparable, procurement data reinforce this contrast. In 2022, less than 4% of US contract obligations went to foreign-owned entities. German evidence (Wolff et al., 2024) also points to a strong domestic/European bias, though non-European suppliers have gained some ground recently.
- 17 | As is common practice in the related literature, firms in the following 2-digit NACE codes sectors are excluded: Agriculture (1-3), Mining & quarrying (5-9), Tobacco (12), Pharma (21), Postal (53), Financial & insurance (64-6) and Real estate (68), Education & Health services (85-8), Arts & recreation (90-3), Public administration (84), Household employers (97-8), Extraterritorial organisations (99). Moreover, the analysis further restricts the sample to firms with non-negative book equity, and due to concerns over data reliability, to those with a median balance sheet total larger than USD 50,000 and a median employment level above three workers. Including these firms does not materially affect the results.
- 18 | This section presents the estimation of the defence premium reported in Figure 1.3b of Chapter 2.
- 19 | Under the log specification, the percentage gap is computed as $100(\exp(\beta) - 1)$.

- 20 | This wage premium may reflect, among others: i) the capital- and technology-intensive nature of defence establishments, ii) the sector's reliance on highly skilled and experienced labour and the need to recruit and retain expertise in areas of acute shortage, iii) the added value contributed by more productive workers, iv) and the distinctive nature of work in defence, which often requires security clearance and specialised training. These results align with Vaze et al. (2017), who find that UK defence sector wages are 20–25% higher than in broader manufacturing, with a residual wage premium of 8%–15% for comparable jobs after adjusting for skills, employee characteristics, and employer attributes.
- 21 | For example, Leonardo's global supply chain includes over 11,000 firms, with more than 4,000 SMEs in Italy alone. Many specialised defence products incorporate components sourced from dual-market suppliers. Naval vessel programmes, for instance, involve hundreds of high-tech component suppliers, from engines to advanced electronics and software. Military production also stimulates demand for metals, chemicals, and other manufactured inputs, as well as logistics, maintenance, and infrastructure services.
- 22 | This section provides background on the estimation of the spillover results discussed in Section 1.3 of Chapter 2 (including those shown in Figure 1.4b).
- 23 | Firm-level TFPR is obtained as the residual from a Cobb–Douglas production function in real value added, with labour (cost of employees) and capital as inputs, each deflated using country-sector-year value-added and investment deflators. Input elasticities are estimated using the control function approach of Olley and Pakes (1996), with real material costs proxying unobserved productivity, and implemented via the single-equation general method of moments framework of Wooldridge (2009) as in Petrin and Levinsohn (2012).
- 24 | This clustering accounts for the correlation in residuals among firms exposed to common sector-year shocks and similar production function estimates, while also capturing cross-country dependence within sector-years. Clustering at the country-sector level does not alter the findings. This alternative aligns with guidance to cluster at the level of the variable of interest in order to capture within-year correlation among similarly exposed firms and serial correlation within country-sectors. Sector-year clustering nonetheless serves as the baseline because in the data, most residual within-firm variation loads at the sector-year rather than the country-sector level; it also produces more conservative standard errors.
- 25 | Identification requires that no omitted country-sector-year shocks simultaneously i) raise defence firm investment intensity in $t-1$ (the lag mitigates mechanical simultaneity but not anticipatory investment) and ii) raise non-defence firms' TFPR in t , conditional on fixed effects and controls. Left for future work, $DefInv_{s,c,t-1}$ could be instrumented using a Bartik style shift-share combining predetermined country-sector exposure to defence firms with exogenous shocks to euro area defence spending (e.g. geopolitical risk shocks or innovations in excess equity returns of prime defence firms).
- 26 | The main regressor is the asset-weighted average investment intensity of defence firms in each (s, c, t) , which is silent about the absolute scale of investment. Thus,

country-sectors with few defence firms but high intensity may appear highly exposed despite few euros invested. To address this, specifications labelled “filter small linkages” exclude observations with very limited defence-firm presence (below the 10th/25th percentile), proxied by the share of defence-firm revenue in sectoral revenue.

- 27 | According to the Aerospace, Security and Defence Industries Association of Europe, sectoral turnover in the EU amounted to approximately €188 billion in 2024, corresponding to about 1% of EU GDP. We abstract from modelling defence exports and imports, as these are of similar magnitude and broadly offset each other in aggregate.