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Challenges for monetary and fiscal policy interactions in the post-pandemic era

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Abstract

In the low inflation and low interest rate environment that prevailed over the period 2013-2020, many argued that besides expansionary monetary policy, expansionary fiscal policy could also support central banks' efforts to bring inflation closer to target. During the pandemic, proper alignment of fiscal and monetary policy was again crucial in promoting a rapid macroeconomic recovery. Since the end of 2021 an environment of higher inflation, lower growth, higher uncertainty, and higher interest rates has changed the nature of the required policy mix and poses different challenges to the interaction between monetary and fiscal policy. Following up on the work done under the ECB's 2020 strategy review (see Debrun et al., 2021), this report explores some of the renewed challenges to monetary and fiscal policy interactions in an environment of high inflation. The main general conclusion is that, with an independent monetary policy that aims to bring inflation back to target in a timely manner, it is still possible to design fiscal policy in a way that protects vulnerable parts of society against the costs of high inflation without pulling against the central bank's effort to tame inflation. This is more likely to be the case if fiscal measures are temporary and targeted, and if priority is given to structural reforms and public investment in support of potential growth. The latter is particularly effective in reshaping the supply side of the economy in a manner that is likely to have a lasting positive structural impact.

JEL: E22, E52, E58, E62,

Key words: monetary policy, fiscal policy, public investment

Executive summary

In the low inflation and low interest rate environment that prevailed over the period 2013-2020, many argued that stronger alignment between monetary and fiscal policy could be beneficial for central banks to bring inflation closer to target. During the pandemic, fiscal and monetary policies were aligned even while working independently, which was crucial to minimising uncertainty and promoting a rapid macroeconomic recovery. Since the end of 2021 an environment of higher inflation, lower growth, higher uncertainty, and higher interest rates has changed the nature of the challenges that these policies face. This technical report follows up on the work done under the ECB's 2020 strategy review (see Debrun et al., 2021) and explores some of the renewed challenges to monetary and fiscal policy interactions in an environment of high inflation.[1]

To study monetary-fiscal policy interactions in a high inflation environment, this report uses a wide range of specialised models in two broad and complementary contexts. In the first context, the focus is on the effects of conventional and unconventional monetary policy under various policy mixes and different fiscal arrangements and operational rules. In the second context, the report deals with the topic of public investment, motivated by initiatives like Next Generation EU, which may generate a challenge to monetary policy in a framework where inflation is above target by boosting demand with a general increase in public investment across the board.

The conclusions of the study can be summarised as answers to four sets of questions.

1. When faced with adverse supply shocks, what consequences and challenges do alternative fiscal measures create for monetary policy?

When shocks generate a trade-off between stabilising inflation and economic activity, monetary and fiscal policy objectives can become misaligned in the sense that meeting them requires different or opposing stances. In 2022/23 many fiscal authorities pursued policies to protect households and firms against elevated energy costs. Insofar as these policies are neither targeted, nor temporary, nor sufficiently backed by future primary surpluses, they may comprise a further challenge to the monetary policy efforts to bring inflation back to target.

The simulations in Chapter 2 (Section 2.2) examine the effects of an adverse supply shock that is accompanied by a set of temporary discretionary fiscal policy measures – a reduction in consumption taxes, an increase in targeted or untargeted transfers and an increase in productive public investment – to assess which of these measures support monetary policy in bringing down inflation. The results show that while they all have a positive impact on private consumption and hence mitigate the adverse impact of the negative supply shock, cuts in consumption taxes and

[1] The work was done by an expert group of staff of the Eurosystem under the aegis of the Working Group on Econometric Modelling, a unit of the Monetary Policy Committee.

increases in public investment have the additional benefit of supporting the monetary authority's effort to bring inflation down faster (compared to a baseline without any fiscal measures). Increases in government investment can enhance the productivity of the private sector and bolster the economy's potential, bringing meaningful relief to upward price pressure. An increase in untargeted transfers cushions the fall in consumption and moderately raises inflation, requires greater outlays by the fiscal authority and implies a stronger build-up of public debt compared with an increase in more targeted fiscal measures.

The economic impact of a negative supply shock also depends on the systematic fiscal policy response and the type of instrument employed by the government. For instance, if it uses countercyclical transfers targeting liquidity-constrained households, the adverse impact this shock has on consumption by these households (and consumption overall) is dampened, while the effect on inflation is not much different compared to the situation without fiscal measures, and the build-up of government debt is lessened. The simulation also illustrates the benefits of employing targeted fiscal measures in response to adverse inflationary shocks.

The distributional consequences of negative supply shocks pose additional challenges to the monetary-fiscal policy mix. Model-based analyses illustrate that the pandemic had adverse effects, not only on aggregate outcomes, but also by disproportionately hurting low-income households. The expansionary monetary and fiscal policies that followed the pandemic helped prevent potentially disruptive developments in financial markets, but also gave rise to adjustments in the returns on real and nominal assets that generated benefits for equity owners and redistributed wealth from younger to older generations. In these circumstances, fiscal policies that directly support household incomes provide more targeted intervention and can therefore stabilise household consumption more effectively, while simultaneously creating space for monetary policy to increase policy rates and preventing inequality from widening.

Distributional aspects of monetary and fiscal policy interactions also arise at the euro area level, due to the role of fiscal risk sharing in shaping the real effects of monetary policy shocks across euro area regions. The empirical evidence provided by this report shows that in the presence of weak fiscal risk sharing, poorer regions experience a more prolonged output contraction in response to a policy rate hike, whereas under strong fiscal risk sharing, poorer regions not only face a weaker output contraction, but are also insulated from potential hysteresis effects.

2. How is the effectiveness of monetary policy in curbing inflation affected by unconventional monetary-fiscal policy arrangements?

Perceived threats to the conventional arrangement of monetary dominance could interact with the monetary policy's effort to bring inflation closer to target and thus warrants closer inspection. Under monetary dominance, which in the euro area is guaranteed by the Treaty on the Functioning of the European Union, the central bank actively targets inflation while fiscal policy is Ricardian in the sense that the fiscal authority ensures its intertemporal budget constraint is satisfied through adjustments in the primary balance. This type of fiscal behaviour implies that, in

general, a contractionary monetary policy that increases public debt is followed by a contractionary fiscal policy aimed at restoring the government's intertemporal budget constraint. Under fiscal dominance, by contrast, the fiscal authority does not behave in a Ricardian manner and the central bank forgoes its inflation target to allow the price level to stabilise public debt. Because in the euro area the ECB has an explicit mandate to preserve price stability and monetary financing of government debt is prohibited by the Treaty, a regime of fiscal dominance is institutionally ruled out. Nonetheless, it remains worth investigating the theoretical implications of departing from monetary dominance for the ability of monetary policy to stabilise inflation, as agents may worry about the emergence of fiscal dominance, despite policymakers' commitment to maintaining monetary dominance.

Excluding the theoretical limiting case of fiscal dominance, the effects of monetary policy have also been analysed under alternative fiscal policy stances in Section 2.3.2. The results show that the impact of a contractionary monetary policy shock on inflation is higher when fiscal policy is also contractionary than when fiscal policy is expansionary (see Kloosterman et al., 2022).[2]

Finally, model-based analyses in Section 2.3.3 show that the effects of monetary policy also depend on the type of operational fiscal rules the fiscal authority faces. These dictate what kind of fiscal adjustments are required once public finances deteriorate, for example after an interest rate hike that raises public borrowing costs. If the fiscal authority faces a structural balance rule, a monetary tightening that worsens the structural balance would call for fiscal tightening that returns the structural balance to target. This reduces output and inflation and amplifies the contractionary effects of monetary policy. If the fiscal authority faces an expenditure growth rule, the required fiscal consolidation following a monetary tightening will be more limited, as the growth rate in primary expenditure is not strongly affected by the monetary policy shock. This renders the effect of the monetary tightening shock on output and inflation more muted than when the fiscal authority faces a structural balance rule.

3. How might the need to undo quantitative easing interact with fiscal policy, financial stability and sovereign bond markets?

In the recent environment of high inflation central banks increased their policy rates and started to unwind some of their quantitative easing (QE) measures. QE policies, as initiated in the euro area by the Asset Purchase Programme in 2014, proved effective in supporting price stability and stimulating economic activity in an environment characterised by persistently low inflation and low real interest rates (Altavilla et al., 2021). The unwinding of these policies can pose challenges for the smooth transmission of monetary policy. Consequently, central banks aim for the run-down of their balance sheets to interfere as little as possible with their policy stance. The possibility of doing so rests on the premise that the effects of such policies are not necessarily symmetrical to QE policies. On the one hand,

[2] As a conceptual caveat, it should be kept in mind that in a monetary union consisting of a single monetary policy with many fiscal policies decided predominantly at the country level it is not immediately clear how to classify fiscal policy as expansionary, unless a multi-country framework addressing issues of coordination between the various fiscal policymakers is used.

quantitative tightening (QT) may have a more limited impact than QE, as the announcement effects of QE (which occurs at the effective lower bound) are likely stronger than those of QT, especially when QT takes place in a gradual and predictable way (Bullard, 2019, and Lane, 2022). On the other hand, the liquidity effect of QT may be more pronounced, as was apparent in the normalisation process of the Fed's balance sheet between 2017 and 2019 (Smith and Valcarcel, 2023).

Monetary policy normalisation can also pose challenges due to the interplay between price stability and financial stability, which in turn could be reinforced by concerns about sovereign debt sustainability. If central banks need to increase policy rates fast and by a significant amount to curb excessively high inflation, these actions could interfere with the stability of the financial system and the need to preserve a smooth monetary transmission. The literature on the interaction between monetary policy normalisation, financial stability and heterogeneous fiscal policies, all in the context of a monetary union, is however still scarce.

4. How does public investment interact with monetary policy in the short run and the long run?

Public investment has been at the forefront of policy and academic debate in the euro area, given the numerous challenges that the currency union is facing; for example, climate change and the green transition, digitalisation, geopolitical risks and an ageing population. Tackling these challenges will likely call for higher public and private investment. The establishment of the NGEU is meant to support Member States in raising public investment and pursuing the structural reforms needed to strengthen the resilience of the currency union.

Given its prominent role in shaping current and future economic conditions, how does public investment interact with monetary policy? The answer to this question has received relatively little attention in the literature and is not straightforward, as increases in public investment could have both positive and negative effects on inflation, depending for instance on whether the impact on output is transitory or permanent.

Harmonised simulations from a wide range of models show that a temporary euro area-wide public investment shock leads to an expansion of economic activity in the short run, a moderate and short-lived increase in inflation, and a temporary rise in the public debt-to-GDP ratio (Section 3.2.1). These expansionary effects prompt a tightening of monetary policy that works to suppress aggregate demand. If the monetary policy response does not occur immediately, the macroeconomic impact is amplified (see also Bouakez et al., 2017; Boehm, 2020; Bonam et al., 2020).

Since fiscal policy in the euro area is decided and implemented at the national level, Section 3.2.2 examines the effects of increases in region-specific public investment. The effects of a temporary region-specific public investment shock differ more across simulations, with the size of the region of origin being a crucial underlying factor. Intuitively, the size of the region determines its weight in the common monetary policy rule and thus the amount by which monetary policy tightens in response to the public investment shock. In general, the smaller the region, the less monetary policy

is tightened and the stronger the output effects of the public investment shock, and vice versa.

Taking a long-term perspective on the effects of fiscal policy requires considering the possibility that public expenditure has a permanent effect on productivity and long-run economic growth. General equilibrium models that feature endogenous growth are particularly suited to studying the transmission channels through which public expenditure can affect long-term growth and how these may interact with monetary policy. In Section 3.3 the report makes use of general equilibrium models featuring endogenous growth to study the long-term effects of fiscal policies and their interactions with monetary policy. In these models, productivity is endogenously related to the amount of investment in research and development (R&D) and the fiscal authority can enhance R&D investment directly, for instance by raising R&D subsidies. The striking conclusion is that an increase in such growth-enhancing public expenditure is generally disinflationary, puts the economy on a higher growth path and yields permanent output gains. While this type of expenditure can have short-term crowding-out effects that reduce private consumption and investment, private spending eventually converges on a permanently higher level. Again, if monetary policy does not immediately contract in response to these expansionary effects, the temporary crowding-out effects can be reduced.

1 Introduction

The euro area architecture builds on standard assignments of separate policy objectives to be achieved by monetary and fiscal policy. As enshrined in the Treaty on the Functioning of the European Union (TFEU),[3] the ECB is independent in the pursuit of its primary objective of maintaining price stability. Fiscal decisions are predominantly taken at the national level and are subject to the rules that characterise the fiscal framework. A key goal of the framework is to support the independence of the ECB and guarantee the sustainability of Member States' sovereign debt. Within this architecture, however, the nature of the interactions between the single monetary policy and national fiscal policies can vary, depending on the macroeconomic environment and, specifically, the inflation outlook.

In an environment where persistently low inflation and low real interest rates prevail, as was the case over the period 2013-2020, monetary and fiscal policies can exhibit strong complementarities (Debrun et al., 2021). Many have argued that stronger alignment between monetary and fiscal policies could support monetary authorities in achieving their inflation objectives. Indeed, research shows that when interest rates are low, the effects of expansionary fiscal policy on inflation and output are stronger (Christiano et al., 2011; Eggertsson, 2011) and the trade-off between economic stabilisation and debt sustainability is relaxed (Blanchard, 2019; Bonam, 2021; Mehrotra and Sergeyev, 2021). It has also been recognised, though, that monetary unions with many fiscally independent Member States offer additional challenges besides those posed by an environment of low inflation and low interest rates.

The pandemic showed that, under certain circumstances, monetary and fiscal policies can reinforce each other even while operating independently. Euro area authorities reacted forcefully to the crisis; government spending increased sharply to support economic activity, while the ECB (which at the time was constrained by the proximity of the effective lower bound, or ELB) took actions to maintain price stability and ensure the stability of the financial system. The measures put in place by the ECB not only guaranteed proper transmission of the monetary policy stance to all parts of the euro area, but also indirectly benefited governments by keeping funding costs low and preventing non-fundamental surges in sovereign risk premia. These measures proved crucial in minimising uncertainty and promoting a quick macroeconomic recovery. In addition, the Next Generation EU (NGEU) initiative was established to increase public investment and promote structural reforms aimed at raising long-run growth, facilitating the green and digital transition, and improving the resilience of the EU.

Since the end of 2021 the macroeconomic environment has changed drastically. The euro area, like many other economies, experienced a rapid surge of inflation to historically high levels, which is creating new challenges for the interactions between

[3] Consolidated version of the Treaty on the Functioning of the European Union, (OJ C 326, 26.10.2012, p. 49).

monetary and fiscal policies. This surge was partly due to a pandemic-related mismatch between supply and demand, but was then dramatically exacerbated by Russia's invasion of Ukraine, which generated an unprecedently large supply shock. In particular, the international price of fossil fuels and other commodities rose rapidly due to increased uncertainty surrounding their international supply. In pursuit of its price stability mandate, the ECB increased interest rates at an unparalleled pace, with the firm intention of bringing inflation down to its target of 2% over the medium term and preventing high levels of inflation from becoming entrenched and inflation expectations unanchored. The need for a restrictive monetary policy stance may contrast with the fiscal policy stabilisation role, particularly when an increase in inflation is to a large extent driven by supply factors (Auclert et al., 2023; Fornaro and Wolf, 2022).

At the time of writing it is not clear whether past and current circumstances will imply structural adjustments and a permanently different regime for the economy, or whether the economy will return to historical regularities once the shocks die out. Regardless of the outcome, different economic circumstances raise specific challenges to the interaction between monetary and fiscal policy and call for a specific policy mix. The current environment of high inflation, lower growth, higher interest rates and elevated uncertainty has certainly changed the nature of the interactions between monetary and fiscal policies that was associated with the prolonged period of low inflation and low interest rates. In fact, in high inflation environments, monetary and fiscal policies are no longer strategic complements – they become substitutes. This means that more active use of one instrument tends to call for less active use of the other, as recognised in the ECB's 2020 monetary policy strategy review (Debrun et al., 2021). From this perspective, monetary and fiscal policies may no longer be sufficiently aligned. For example, measures implemented by fiscal authorities to protect households and firms from rising energy costs may challenge the central bank's efforts to bring inflation down to target (see, for example, Bańkowski et al., 2023). These fiscal measures may also raise concerns regarding their detrimental impact on public finances and the potential resurgence of fragmentation within the euro area. In contrast, other types of fiscal policies, such as growth-enhancing public investment, could help bring down inflation by supporting the supply side of the economy.[4]

In the current environment, where fiscal measures in some jurisdictions may have been contributing to inflation at a time when price pressures persist, improved alignment of monetary and fiscal policies would be beneficial. In their pursuit of stabilising their economies, governments could choose to implement targeted and tailored measures that temporarily support vulnerable households and firms, while at the same time focusing on structural aspects of the economy. The latter may require, among other things, public investment and structural reforms to raise potential growth, which could contribute to more benign public debt dynamics (through the denominator effect) and help reduce medium-term inflationary pressures by reducing supply-side constraints.

[4] For a comprehensive literature review on monetary and fiscal policy interactions, see Section 2.1.

This report explores some of the renewed challenges to monetary and fiscal policy interactions in an environment of high inflation. The analysis is based on several models, and draws on insights from existing literature. All models used in the report have been carefully selected to fill some of the gaps identified in the previous report on the same topic (Debrun et al., 2021), as well as to reflect the balance between their availability in the current suite of models of the European System of Central Banks (ESCB) and the complexity of the topic, which almost inevitably requires specialised models to analyse different questions. A detailed list of the models used, including a summary description of their main characteristics, can be found in the Annex at the end of this report.

The report is structured around two main chapters that follow this introduction. Each starts with a comprehensive and up-to-date literature review.

Chapter 2 analyses the interactions between monetary and fiscal policies under monetary dominance (a situation where the monetary authority is committed to maintain price stability, while the fiscal authority ensures the sustainability of government debt) and under different fiscal arrangements and operational fiscal rules, including the theoretical possibility of fiscal dominance. Targeted boxes address distributional issues related to the interaction between monetary and fiscal policy, as well as the specific issue of moving from quantitative easing (QE) to quantitative tightening (QT).

Chapter 3 examines the effects of public investment. The chapter is motivated by initiatives such as NGEU which, through its potentially expansionary impact on aggregate demand, may generate a challenge to monetary policy in an environment where inflation is already above target. Dedicated boxes address the effects of public investment at the effective lower bound (ELB), the effects of NGEU and the implications of endogenous growth for government debt sustainability.

The analyses show that with an independent monetary policy aimed at bringing inflation back to target in a timely manner, fiscal policy choices can be designed to provide protection to the vulnerable parts of society while still avoiding pulling significantly against the need to tame inflation. This is particularly true if fiscal measures are temporary and targeted, and if priority is given to reforms and public investment in support of potential growth.

Even though it covers a wide range of analyses and employs many different types of macroeconomic models, this report is by no means an exhaustive treatment of monetary and fiscal policy interactions. Beyond the questions addressed are a plethora of related policy questions it does not fully cover and which the models used are not able to deal with properly. These include the distributional effects of adverse supply or energy shocks and the role of optimal monetary and fiscal policy, the interplay between monetary policy and financial stability, the role of inflation expectations and uncertainty, the effects of sectoral reallocation costs on inflation and how monetary and fiscal policy should respond to such costs, and the implications of central fiscal capacity for the optimal monetary-fiscal policy mix. The objective of this report is to focus on two pressing policy issues: the effects of conventional and unconventional monetary policy, and public investment in a time of

high inflation, with a particular emphasis on the interaction between monetary and fiscal policy.

2 Challenges to monetary-fiscal policy interactions in a high inflation environment

Given the inflation surge that started in late 2021, monetary and fiscal policies in the euro area no longer seem aligned. The ECB has removed accommodation to control inflation, while fiscal authorities have implemented mostly untargeted measures to protect households and firms from rising energy costs – which may challenge the monetary policy efforts to bring inflation down to target. This chapter looks at the interactions between monetary and fiscal policies in a high inflation environment.

2.1 Literature review on monetary-fiscal policy interactions

This section provides an overview of the literature on monetary-fiscal policy interactions, and how the nature and importance of these interactions differ across environments characterised by low and high inflation and interest rates.[5]

2.1.1 Complementarities in a low inflation and low interest rate environment

The monetary policy independence enshrined in the statutes of most central banks builds on a separation of roles, with monetary policy responsible for ensuring price stability and fiscal policy for guaranteeing public debt sustainability. The fundamental interaction between monetary and fiscal policies derives from the consolidated budget constraint on the public sector. On a consolidated basis, government expenditure can be financed through taxes and by issuing public debt and currency. If the stream of future primary balances was perceived to be insufficient to cover the current level of public debt, and if monetary policy was compelled to ensure the intertemporal budget constraint (IBC) was satisfied, then the central bank might not be able to control inflation. In such a regime of fiscal dominance, Sargent and Wallace (1981) show that the central bank would need to allow seignorage revenues and inflation to increase persistently. For that reason, monetary dominance, a regime where fiscal policy is chosen to satisfy the IBC for any given monetary policy trajectory, has been considered a necessary condition for the pursuit of a central bank's price stability mandate.

In a low inflation and low interest rate environment, fiscal policy may be more effective and can play a stronger role as stabilisation tool. To the extent that expansionary fiscal policy raises aggregate demand, it may temporarily induce

[5] This section includes contributions from Dennis Bonam (De Nederlandsche Bank), José Cardoso da Costa (Banco de Portugal) and Stéphane Moyen (Deutsche Bundesbank).

somewhat higher inflation. If this has some impact on short-term inflation expectations and the nominal interest rate is limited by the ELB, then the real interest rate may fall. A lower real interest rate, in turn, promotes private consumption and investment, which amplifies the rise in aggregate demand. Therefore, rather than exerting the standard crowding-out effects that would arise when the nominal interest rate lies above the ELB, expansionary fiscal policy could in fact have crowding-in effects when the ELB is binding (Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011). Moreover, low interest rates help suppress the cost of public borrowing and thereby relax the trade-off between economic stabilisation and debt sustainability that fiscal policy could face (Bonam, 2021), especially if the interest-growth differential turns negative, as was the case for a large part of the last two decades (Blanchard, 2019; Mehrotra and Sergeyev, 2021).[6]

Monetary policy may benefit from fiscal backing to escape persistently low inflation episodes when the nominal interest rate is close to the ELB. The declining trend in the natural rate of interest observed over the past few decades has shrunk the space for monetary accommodation, weakening the ability of conventional monetary policy to increase inflation when it falls below the central bank's inflation target (Del Negro et al., 2017; Kiley and Roberts, 2017; Bonam et al., 2018). The effectiveness of changes in the nominal interest rate, the traditional instrument of monetary policy, is severely affected when the ELB is binding.[7] In these circumstances, in addition to the use of unconventional monetary policies such as quantitative easing, forward guidance and negative interest rates, some authors suggested that fiscal backing might be needed to ensure price stability (Cochrane, 2011; Del Negro and Sims, 2015).

2.1.2 Challenges in a high inflation environment

A high inflation environment worsens the trade-offs faced by monetary and fiscal policies, especially when inflation is mainly driven by supply factors. Monetary policy faces a challenging choice between gradually increasing the policy rate while pondering the high uncertainty over the size and duration of the adverse supply shock and its effects on the real economy, and a stronger response that reduces the risks of inflation remaining noticeably above the objective for a protracted period. Under monetary dominance, an inflationary shock calls for a monetary policy response that typically reduces fiscal space, as higher interest rates put pressure on debt service costs, thus reducing the room fiscal policy has to adopt a macroeconomic stabilisation role. When inflation is mainly driven by supply factors, this trade-off is further exacerbated, as lower economic activity puts additional pressure on public finances (Auclert et al., 2023; Fornaro and Wolf, 2022).

Interest-growth differentials are prone to reversal risks that could raise concerns about debt sustainability. The central bank can play an important

6 For the euro area, Fuest and Gros (2019) and Checherita-Westphal and Domingues Semeano (2021) show that the interest rate-growth differential has been positive on average since the 1980s.

7 Benhabib, Schmitt-Grohé and Uribe (2001) show that, in the presence of the ELB, a monetary policy rule under the Taylor principle may push the economy into an "unintended equilibrium" of low or negative inflation.

role in avoiding self-fulfilling debt crises. As monetary policy tries to rein in inflation, interest costs may increase and reduce fiscal space. Lian et al. (2021) show that countries with high public debt levels are particularly prone to a reversal of the interest-growth differential from negative to positive. Concerns about debt sustainability may arise in such cases, pushing up sovereign risk premia and further increasing public borrowing costs. Self-fulfilling equilibria may arise when there is uncertainty about the sustainability of public debt, but can be avoided if the central bank acts as a backstop for government funding. Corsetti and Dedola (2016), for example, show that the central bank can help coordinate expectations away from such equilibria by issuing monetary liabilities in exchange for public debt securities and thus reducing the interest rate on public debt. If risks are not fundamental, these actions do not generate higher inflation and may be key to controlling inflation expectations. In a monetary union, they are also crucial to ensure the singleness of monetary policy and a proper transmission of monetary policy in all economies.[8]

Even occasional departures from monetary dominance may result in higher inflation and risk de-anchoring inflation expectations. A growing literature has considered the possibility of the economy cycling through different policy regimes, and what this implies for macroeconomic stability. Davig and Leeper (2007), for example, show that price stability can still be ensured in a model where the central bank does not always actively target inflation, as long as such occurrences are sufficiently short-lived. However, Bianchi and Melosi (2013) and Bianchi and Ilut (2017) show for the US that such monetary policy regime changes may have accounted for the relatively slow transition to the high inflation period of the 1970s. On the other hand, this theoretical strand of the literature also suggests there are potential benefits to allowing a temporary regime of active fiscal policy that increases inflation, especially when the frequency of hitting the ELB is high (Bianchi and Melosi, 2022; Billi and Walsh, 2022). Bonam and Hobijn (2020) show, in a theoretical model, that such temporary regimes of active fiscal policy are also feasible in a monetary union, as long as the fiscal authorities commit to returning to policies that will ensure future debt sustainability.

Unexpected inflation might help reduce the real value of public debt if the inflation surprise is persistent and debt maturity relatively long. Unexpected inflation played an important role in financing large public debt spurts in specific historical episodes, namely those related to wars (Hall and Sargent, 2010, 2022; Ellison and Scott, 2020). In models with traditional sticky price rigidities, the inflation volatility needed to deflate public debt would be too costly, but under alternative environments and with full commitment, moderate and persistent inflation can be optimal (Teles and Tristani, 2021). A crucial factor for this is that the maturity of public debt must be sufficiently long, which implies that a smaller increase in inflation is needed to reduce the real value of outstanding public debt (Leeper and Zhou, 2021; Cochrane, 2022). It is important, however, to keep in mind that what matters is the maturity of consolidated public-sector liabilities, including currency and central bank reserves. While many governments have increased the maturity of public debt, the expansion in central banks' holdings of sovereign debt securities in the past

[8] In an incomplete monetary union, fears of capital losses at the level of the national central bank may reduce the incentives to coordinate on such a policy role (Corsetti et al., 2019).

decade financed by reserves has generally worked to reduce the maturity of liabilities held by the private sector, thus implying that much higher inflation is needed for a given reduction in the market value of public debt.

Large balance sheet exposures to interest rate risk leave central banks vulnerable to income losses, which could have a temporary negative impact on public finances. As their asset purchases are largely financed by interest-bearing reserves, the risk of central banks losing control of the price stability objective due to balance sheet losses is theoretically possible, but would be very unlikely in practice. In particular, any short-term losses from higher policy rates would likely be compensated by higher future seignorage revenues, as long as the credibility of the domestic currency remains intact. This has been highlighted by Bassetto and Messer (2013), Del Negro and Sims (2015) and Benigno and Nisticò (2020). Belhocine et al. (2023) project the net income of the Eurosystem over the next ten years and conclude that while the recent increase in policy rates implies significant losses for some time, net income is expected to recover relatively strongly. The authors make the case that losses should be covered by future profits, obviating the need for capital injections, meaning that the fiscal implications, while not negligible, would be moderate. Nonetheless, the arrangements governing transfers between monetary and fiscal authorities should ensure that monetary policy decisions are not contaminated by concerns over potential short-term losses. In a monetary union, this implies maintaining credible dividend and provisioning policies, as the financial credibility of each national central bank (NCB) may be important to ensure the price stability objective at the aggregate level (Bassetto and Caracciolo, 2021).

2.2 An assessment under monetary dominance based on structural/semi-structural models

In this section we analyse the possible challenges posed by the response of fiscal authorities to a negative supply-driven shock to the monetary policy objective of bringing inflation closer to target. We look at the issue through the lens of two classes of models: structural models, including the Euro Area and the Global Economy (EAGLE) model and a canonical medium-scale New Keynesian model calibrated to the euro area, and semi-structural models, namely ECB-BASE.[9] All models calibrated or estimated on the euro area are characterised by monetary dominance with no risk of entering a fiscal dominance regime, which is consistent with the institutional framework and evidence reported by Debrun et al. (2021).

Different fiscal policy actions have a different impact on inflation and economic activity, and as such interact with the ability of the central bank to stabilise inflation close to target. When shocks occur that generate a trade-off between stabilising inflation and economic activity, monetary and fiscal policy objectives can easily become misaligned in the sense that meeting them requires opposite stances. Although it is not the goal of fiscal policy to stabilise inflation, some

[9] For details of the models see the Annex.

fiscal policy actions may nevertheless influence the effort by the central bank in bringing inflation down to target. First, the implementation of public investment plans may have an uncertain impact on inflation. Even though public investment is not a stabilisation instrument, fiscal policy that supports a build-up of productive capital to lift supply could temporarily exert downward pressure on inflation while at the same time supporting demand in the short term, which would have the opposite effect on it. Second, if fiscal policy directly cuts consumption taxes to support household purchasing power in the face of negative supply shocks (as in the recent euro area experience), it may have an immediate effect on final consumer prices, but may also have an upward effect on inflation via increased demand. Finally, fiscal policy can protect the income of the most vulnerable with targeted transfers, easing the social cost of monetary tightening or any other adverse shocks that depress income and/or put upward pressure on prices. Analysing the impact of these alternative policy measures and the channels through which they interact with monetary policy calls for the use of structural and semi-structural models.

2.2.1 Simulations with the EAGLE model

In this section we look at the impact of different fiscal policy actions in response to a negative supply-driven shock through the lens of the EAGLE model. [10,11] We simulate an inflationary cost-push shock in a version of the EAGLE model that features an extended fiscal bloc.[12] Then we look at the impact of different discretionary fiscal policy measures. We consider a stylised one-year cost-push shock that hits the world economy and drives up annual euro area inflation by around 1 percentage point while reducing economic activity.[13] The discretionary fiscal policy measures aimed at cushioning the impact of this shock considered include a reduction in consumption taxes, an increase in untargeted transfers and an increase in productive public investment, in all cases amounting to 0.5% of pre-shock GDP and implemented for four years.[14] We also consider the case of targeted transfers providing roughly the same support to constrained households' consumption as in the case of untargeted transfers (but giving no support to unconstrained households). The fiscal rule that stabilises public debt using lump-sum taxes is inactive over this period. Results are shown as deviations from the baseline scenario of the negative supply shock with no fiscal measures.

In the face of an inflationary cost-push shock, different choices by the fiscal authority impact the monetary authority's ability to bring inflation closer to target over the short run in various ways. Chart 1 summarises the

10 Includes contributions from José Cardoso da Costa (Banco de Portugal), Sandra Gomes (Banco de Portugal) and Pascal Jacquinot (ECB).

11 The results are based on Campos et al. (2023).

12 For a description of the model see the Annex (EAGLE6). Simulations are run under perfect foresight.

13 The shock is implemented in both the tradeable and non-tradeable sectors. After one year the shock dies out according to an AR(1) process with the parameter equal to 0.6. In quarterly terms, the maximum increase in quarterly year-on-year inflation happens at the beginning of year 2.

14 As mentioned above, while the increase in public investment should not be regarded as specifically tailored to counter the shock at cyclical frequencies, it is nevertheless instructive to analyse it, since public capital accumulation affects both aggregate demand (in the short term) and aggregate supply (in the medium to long term).

macroeconomic implications of the different fiscal measures. Cuts in consumption taxes mitigate the inflationary shock in the short run, but the effect is short-lived as it also supports economic activity and hence requires a slightly stronger monetary policy response, and once the measure unwinds the opposite impact applies. Increases in public investment, by contrast, have a negligible impact on inflation in the short run, but a relatively strong impact in the medium term, supporting the monetary authority's effort to bring down inflation with a milder increase in the policy rate. An increase in transfers cushions the fall in consumption and economic activity with a mild increase in inflation, so the monetary authority needs to raise the policy rate somewhat more strongly (see Chart 1). In this model, untargeted transfers do not directly affect the choices of unconstrained households because they are lump-sum (that is, non-distortionary) and unconstrained households behave in a Ricardian fashion. For this reason, the macroeconomic impact of targeted and untargeted transfers is identical, except for the fiscal cost. However, if the behaviour of some unconstrained households were to include non-Ricardian features, then untargeted transfers would imply an additional rise in inflationary pressures relative to the targeted transfers scenario.[15]

The rise in public debt following the cost-push shock is accentuated, especially over the medium run, when policymakers implement the different fiscal measures. The cost-push shock implies an increase in inflation, which typically has a favourable impact on public debt, but this is more than offset by a strong decline in economic activity. The contraction in output leads to lower tax revenues, causing the primary balance to drop. At the same time, the central bank hikes policy rates to offset the increase in inflation, increasing interest costs and amplifying the increase in public debt.[16] The different fiscal policy measures imply either an increase in fiscal spending or a decrease in fiscal revenue, accentuating the increase in public debt. Given that an increase in public investment has the greatest positive impact on economic activity, this is associated with the smallest build-up in public debt of the various measures and is identical to the impact under the targeted transfers scenario, where the direct fiscal cost is smaller than the other three scenarios. Moreover, since public investment helps bring down inflation more persistently, monetary policy can reverse its tightening and lower the interest rate more quickly, which also helps dampen the rise in public debt. Note that our simulations consider public investment that helps raise firms' productivity, which may explain the favourable macroeconomic impact.[17]

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15 The medium-term negative impact increases in targeted and untargeted transfers have on GDP comes from significantly lower investment (the crowding-out effect) and a decrease in the labour supply (the wealth effect).

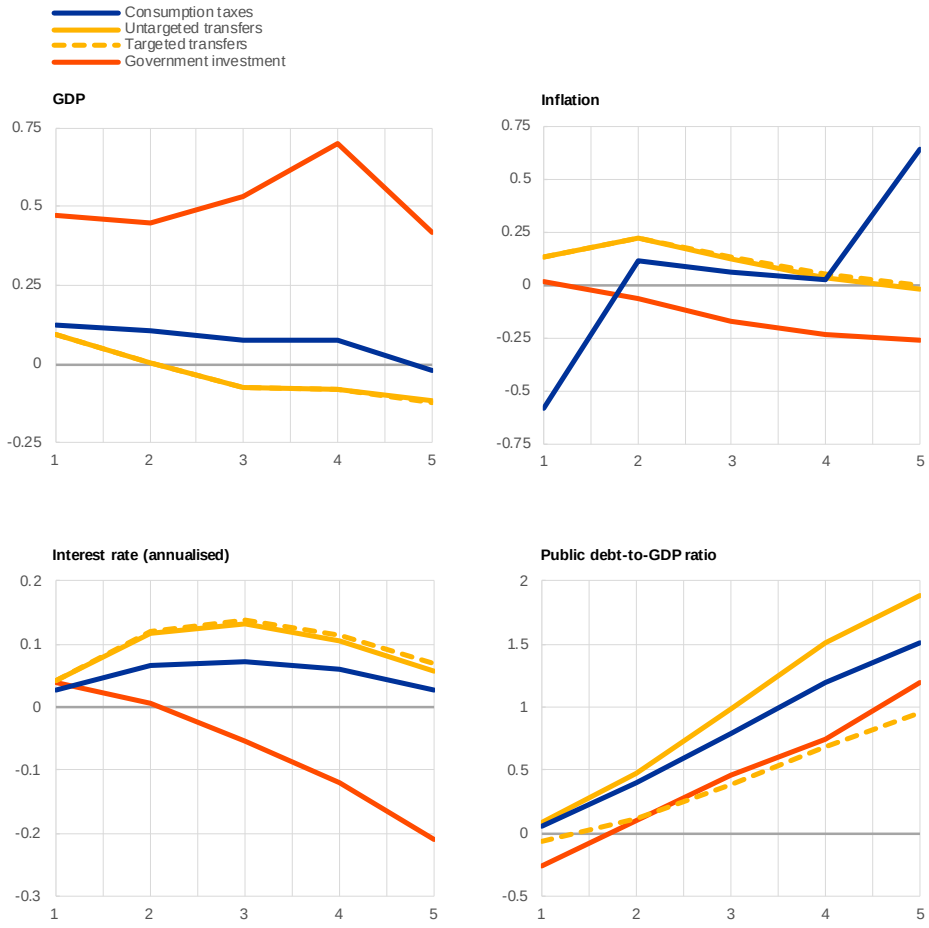
16 The model only includes one-period public debt, so the impact of an increase in interest rates feeds through to public debt more quickly compared to a model that includes longer-term debt.

17 For a discussion of the impact of public investment shocks see Chapter 3.

Chart 1

The EAGLE model – macroeconomic impact of fiscal policy measures

(y-axes: percentage/percentage point deviations from baseline; x-axes: years)



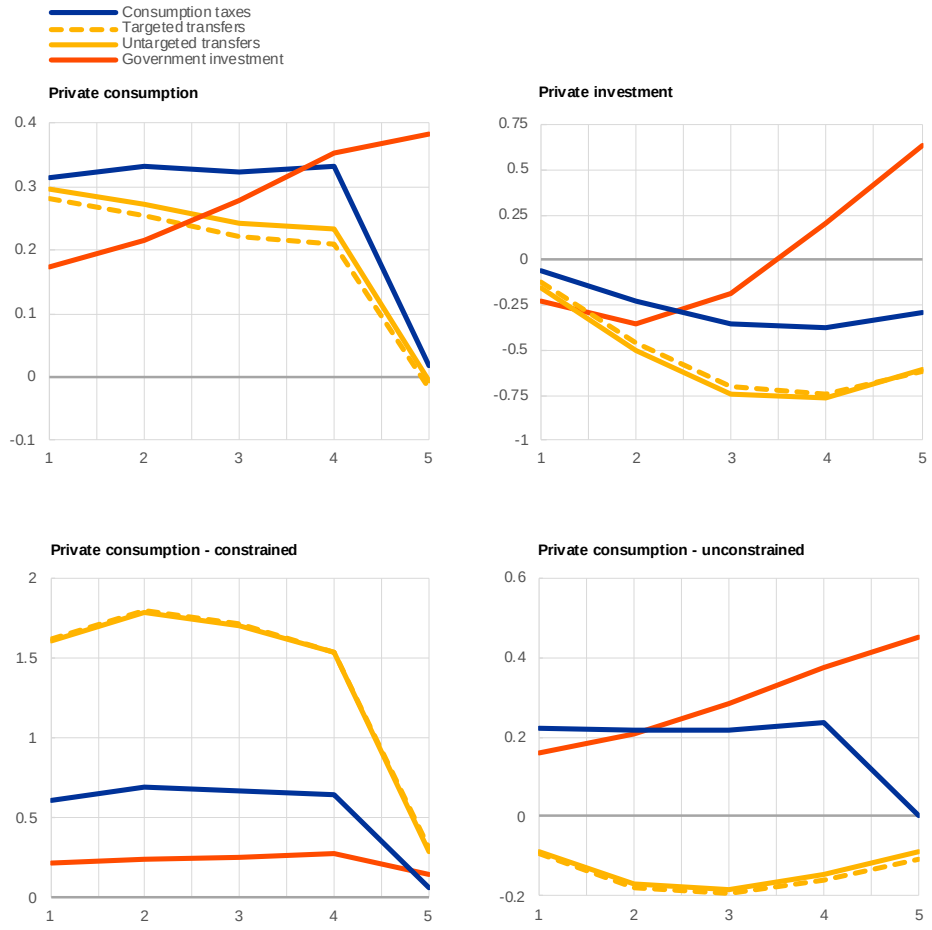
Source: Authors' calculations based on Campos et al. (2023).
Notes: GDP expressed as percentage deviations from the steady state. All other variables are shown as percentage point deviations from steady state.

All fiscal measures simulated have a short-run positive impact on economic activity, partly mitigating the impact of the supply shock via the support from private consumption (see Chart 2)**.** All measures support aggregate private consumption, in particular consumption by constrained households, especially in the case of transfers. The consumption of unconstrained households is slightly negatively affected in the latter instance, as transfers do not directly affect their decision but the increase in interest rates leads to an intertemporal shift to the future. While the measures support aggregate private consumption, private investment performs worse due to lower savings.

Chart 2

The EAGLE model – impact on domestic demand components of fiscal policy measures

(y-axes: percentage deviations from baseline; x-axes: years)



Source: Authors' calculations based on Campos et al. (2023).

Fiscal transfers targeted at constrained households result in similar support for consumption, but at a smaller fiscal cost. Targeted transfers imply similar responses of GDP, consumption and inflation compared to the untargeted transfers scenario because the support to constrained agents is similar in both cases, while, as mentioned before, unconstrained agents are not influenced directly by the transfers. One crucial difference implied by the shock to targeted transfers is that the fiscal authority faces lower outlays and thus a more favourable trajectory of public debt compared to the untargeted transfers scenario.

The different fiscal measures have a heterogeneous impact among consumers. The ability to study heterogeneity in the EAGLE model is limited, as it only differentiates between two groups of consumers. The analysis in Box 1 uses a HANK model to analyse the aggregate and distributional effects of inflationary cost-push shocks, as well as of different fiscal policy options. Box 2 uses an OLG model to analyse how the fiscal and monetary expansion in the euro area in response to the pandemic redistributed wealth between age cohorts.

The analysis above can be extended along several dimensions. First, it is based on a single model that rests on several assumptions. In the next section we use an alternative semi-structural model which, among other differences, rests on a different expectation formation mechanism. Second, we rely on discretionary fiscal measures, but the analysis of alternative fiscal rules is also of interest; this is done in Section 2.2.3. Third, public investment is assumed to be productive, which may not always be consistent with what is actually observed. By changing some features of the model it would be possible to reduce the effectiveness of public investment in raising productivity, for example allowing for time-to-build technology or requiring import content in public investment. Chapter 3 analyses the impact of public investment in more detail. Finally, different degrees of private and public risk sharing in a monetary union may change the transmission of shocks, an issue which is explored in Box 3.

2.2.2 Simulations with the ECB-BASE model

This section again investigates how fiscal policy measures interact with the efforts of monetary policy to bring inflation down to the target, but this time through the lens of the ECB-BASE model.[18] We explore several options for fiscal policy measures and assess their impact on economic activity and inflation.[19] In particular, the following fiscal policy measures are considered: (1) a cut to consumption taxes, aimed at directly reducing the final prices of consumed goods and services; (2) an expansion in social transfers to households, with a view to supporting their real disposable income; and (3) a boost to productive government investment, to address the supply-side constraints which largely underpinned the initial inflationary pressures. The impact of these initiatives on output and inflation and their fiscal costs are analysed. It is important to note that unlike EAGLE, in ECB-BASE expectations are not model-consistent and are based on a backward-looking VAR model. In this framework the role of past macroeconomic dynamics in determining the response to shocks is substantial. In addition, future considerations do not play much of a part, which eliminates anticipation effects. One meaningful consequence of this framework is a breakdown in Ricardian equivalence. Consequently, increases in government debt are not associated with any need to adjust tax or spending policies in future.

The shocks underpinning each fiscal measure are consistent with the design of the EAGLE simulations in the previous section. Specifically, in each scenario a relevant policy instrument is shocked by 0.5% of GDP ex ante. The shocks last four years and unwind instantaneously thereafter.[20] Given the pre-specified measure, the following fiscal instruments are subject to shocks: consumption tax

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18 Includes contributions from Krzysztof Bańkowski and Kai Christoffel (both ECB).

19 Bańkowski et al. (2023) estimate that the fiscal measures embedded in the December 2022 Eurosystem projections have a positive effect on GDP growth and reduce inflationary pressures in 2022 and 2023.

20 The reference baseline is broadly consistent with the Eurosystem's projections (ESCB, December 2022) up until the fourth quarter of 2025, and model-based afterwards. It embeds the ongoing, extraordinarily high inflationary pressures, no major output gap and some normalisation of public finances in the euro area, as evident in the declining ratios of deficit and debt to GDP. It is worth noting that, outside the areas with strong non-linearities (e.g. the ELB), shock simulations tend to be only minimally dependent on the baseline.

rate, government transfers and government investment.[21] Monetary policy is endogenous, which means that the central bank reacts to the effects induced by fiscal policy.[22] The results are summarised in Chart 3.

The simulations indicate that fiscal policy interventions can have markedly different effects, depending on the instrument applied. First, cuts to consumption taxes can meaningfully bring down inflation, given the direct link between the two. However, this comes with a flip side in the sense that, once the shock unwinds, the opposite effect occurs, and inflation increases. Second, untargeted government transfers neither greatly affect output nor inflation. This is explained by the relatively low output multiplier in the model associated with this category, given that a substantial portion of transfers is essentially saved by non-liquidity-constrained households. Finally, an attempt to stimulate supply by increasing productive public investment adds significantly to aggregate demand in the short term and hardly reduces inflation in the medium term. This result stands in contrast with the findings of the EAGLE model, where boosting potential output through government investment generates a decline in inflation over the medium run. While government investment in the ECB-BASE model is not wasteful, it contributes to the productive stock of total economy's capital the same way as private investment. In the EAGLE model, government investment augments the productivity of private capital in a similar manner to technological progress, thus making this instrument particularly potent.[23]

All fiscal measures considered create an additional burden for public finances, although the magnitude differs. The overall fiscal cost can be inferred from the reaction in the debt-to-GDP ratio. A reduction in consumption taxes is deemed the most expensive, because this reduces tax revenue and temporarily brings down nominal GDP. In this situation, the debt-to-GDP ratio not only increases because of the deterioration in the budget balance, but also due to the denominator effect. By comparison, the changes to the debt ratio brought about by government investment are relatively benign, even proving favourable in the short term. In this instance public finances bear a cost, but also reap benefits from the strong stimulative effects of this instrument.

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21 In ECB-BASE, government transfers affect the overall disposable income of households without distinguishing between Ricardian and non-Ricardian types. Nevertheless, private consumption is determined as a sum of the two kinds of households. Ricardians optimise their consumption intertemporarily, in line with the permanent income hypothesis, while non-Ricardians link it to the growth in overall disposable income.

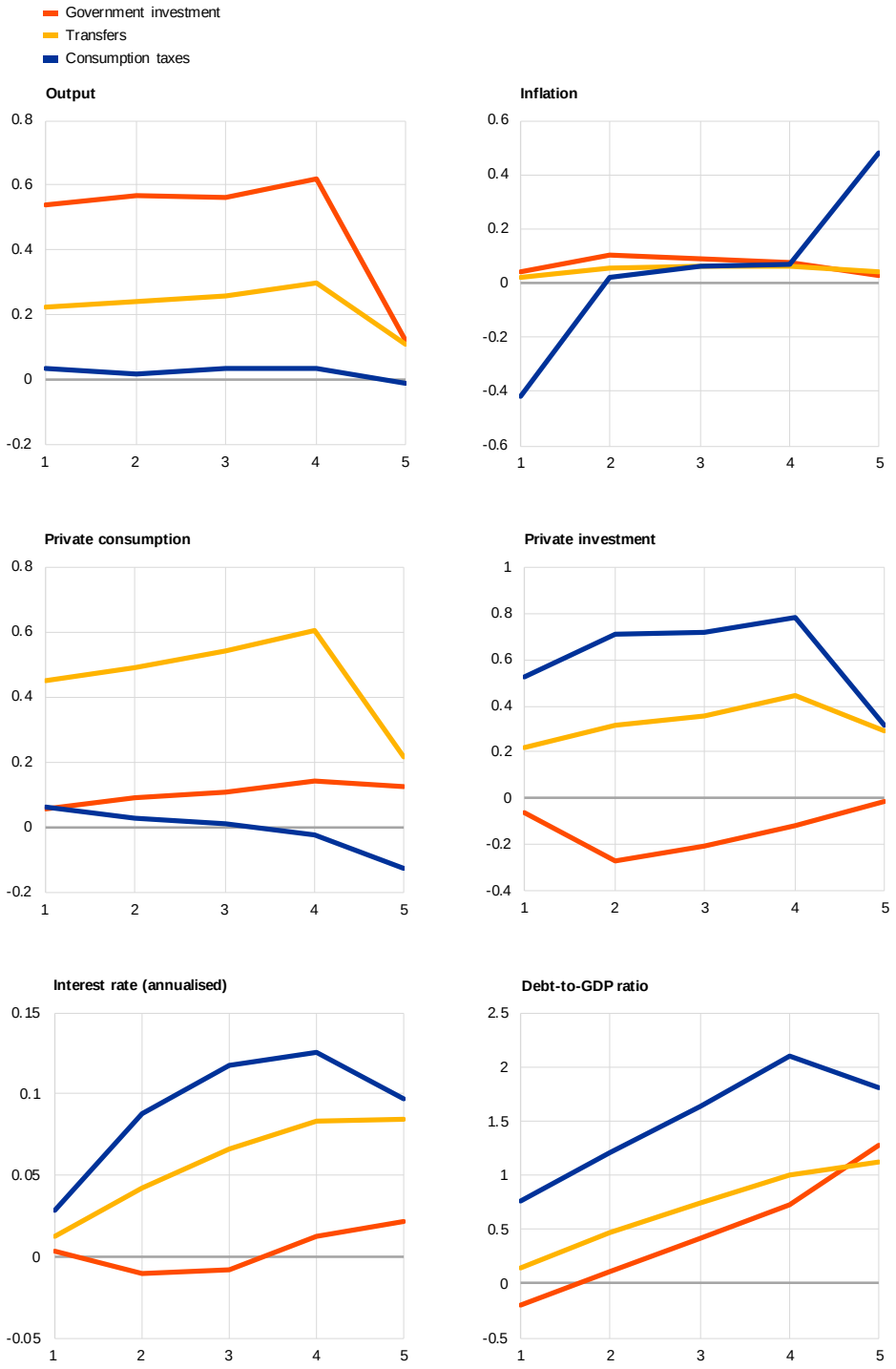
22 In the case of the consumption tax cut, the central bank overlooks the immediate impacts of the tax rate reduction on inflation, responding solely to the inherent inflationary pressures.

23 The different efficacy of public investment between forward and backward-looking model can be related to the expectation formation process. In forward-looking models with rational expectations, the positive effect of government investment on the overall capital stock and the implied increase in total factor productivity is anticipated, yielding instant benefits. Under backward looking expectations, only realised increases in the capital stock are relevant for the productive capacity of the economy.

Chart 3

The ECB-BASE model – macroeconomic impact of fiscal policy measures

(y-axes: percentage/percentage point deviations from baseline; x-axes: years)



Source: Authors' calculations using ECB-BASE.
Notes: GDP, consumption and investment expressed as percentage deviations from the steady state. All other variables as deviations from steady state.

2.2.3 Simulations with a canonical medium-scale New Keynesian model

The previous sections considered a variety of fiscal instruments exogenously activated in response to an inflationary cost-push shock.[24] As a complement to that analysis, this section considers the effects of alternative fiscal rules within a closed-economy model of the euro area.[25]

How the economy responds to shocks depends on the type of instrument the government employs when engaging in fiscal adjustments. To illustrate this point, Chart 4 shows the responses to an inflationary cost-push shock that delivers an increase of 1 percentage point in annualised euro area inflation on impact, which subsequently gradually reverts to its steady-state level. Output falls accordingly. An important feature of the model is that some of the households (25%) are non-optimising "rule-of-thumb" (ROT) households who spend all their disposable income on consumption and do not save. Unlike the analysis presented in the previous section based on the EAGLE and ECB-BASE models, in this case the fiscal authority makes use of alternative fiscal instruments by means of systematic fiscal rules, as opposed to exogenously choosing each instrument. Specifically, two scenarios are considered that differ in the type of fiscal instrument used in the fiscal rule implemented by the government: (1) untargeted lump-sum transfers are adjusted to stabilise government debt but no other fiscal instrument is used (solid blue lines),[26] and (2) the government countercyclically raises targeted transfers to ROT (constrained) households (yellow dashed lines).[27] Regardless of the type of fiscal instrument and rule used, the cost-push shock always leads to a rise in inflation and a decline in output and its components. The rise in inflation prompts a contraction in monetary policy and the interest rate rises, which in turn lowers consumption. Note that the fall in consumption is most pronounced for the ROT households.

Countercyclical transfers to households help to stabilise consumption following an inflationary shock, without generating too much additional inflationary pressure. As shown in Chart 4, when the government employs countercyclical targeted transfers the drop in consumption by constrained households is substantially reduced compared to the baseline scenario.[28] Since these households have a relatively high marginal propensity to consume, the rise in their disposable income (compared to the benchmark case) due to the targeted transfers allows them to reduce the consumption loss they incur because of the shock. Despite its stabilising effect on consumption, the rise in transfers to constrained households does not deliver any strong inflationary effects compared to the baseline, thus avoiding the need for a stronger monetary contraction. The fall in

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24 This section includes contributions from Alessandro Notarpietro (Banca d'Italia).

25 For a general description of the model, except for the fiscal bloc, see Busetti et al. (2021).

26 The fiscal rule based on untargeted transfers (or taxes) is suspended in the initial four quarters and subsequently activated to stabilise the government debt-to-GDP ratio.

27 As in the previous scenario, untargeted lump-sum transfers are kept constant for the first four quarters. The rule governing the behaviour of targeted transfers is always in place, however. In both rules, the fiscal instrument responds to deviations in output from the steady-state level.

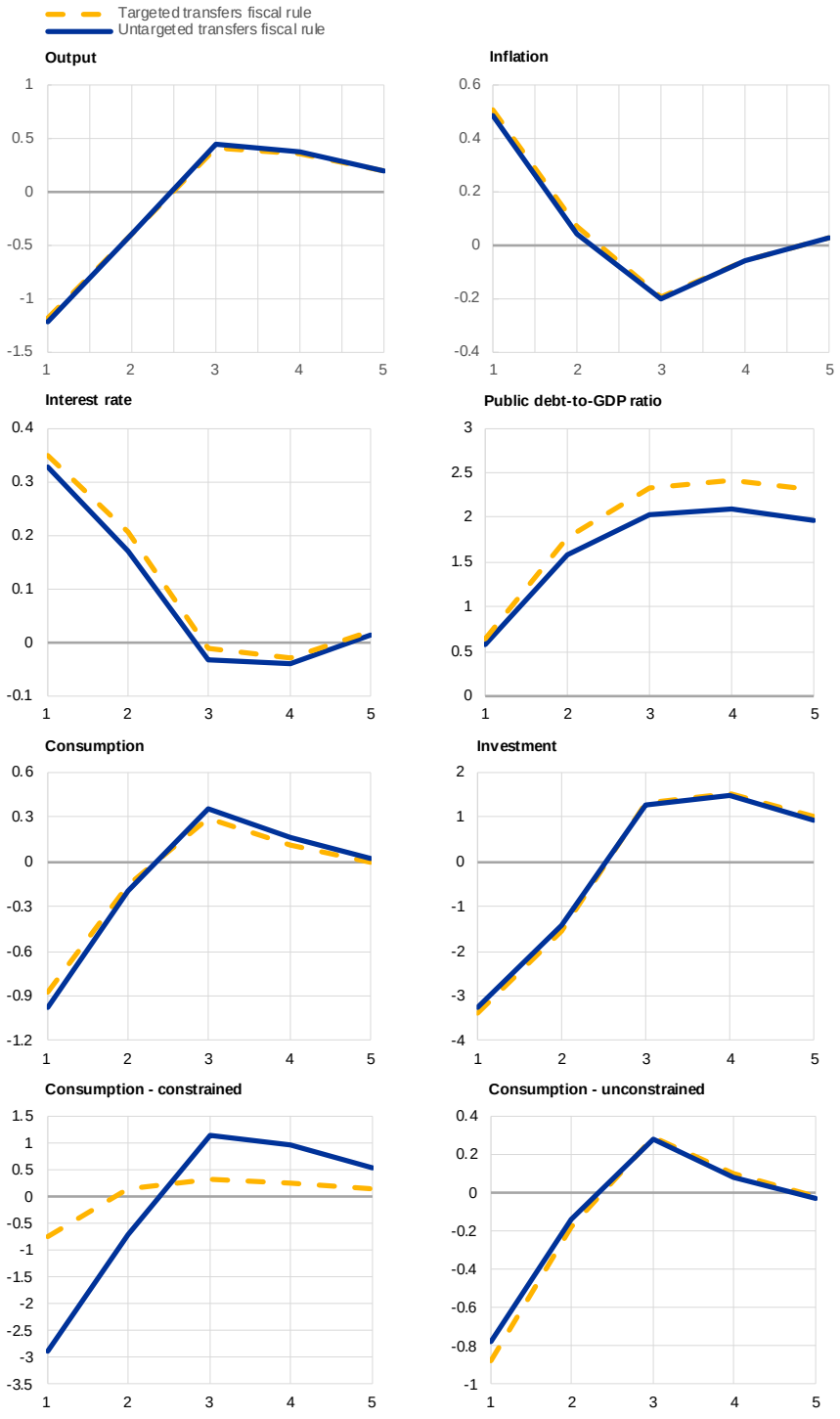
28 In the example shown in the chart, the calibration of the ROT-targeted transfers rule is chosen in such a way as to broadly equalise the fall in consumption by both Ricardian and ROT consumers.

aggregate consumption is also slightly attenuated. Countercyclical targeted transfers imply a temporary increase in government debt in response to the inflationary shock.

Chart 4

A negative cost-push shock under alternative fiscal policy responses

(y-axes: percentage/percentage point deviations from the baseline; x-axes: years)



Source: Authors' calculations.
Note: GDP, consumption (total, constrained and unconstrained) and investment are expressed as percentage deviations from the steady state. All other variables are shown as percentage point deviations from steady state.

Box 1 Monetary and fiscal policy interactions and inequality in the face of an inflationary shock

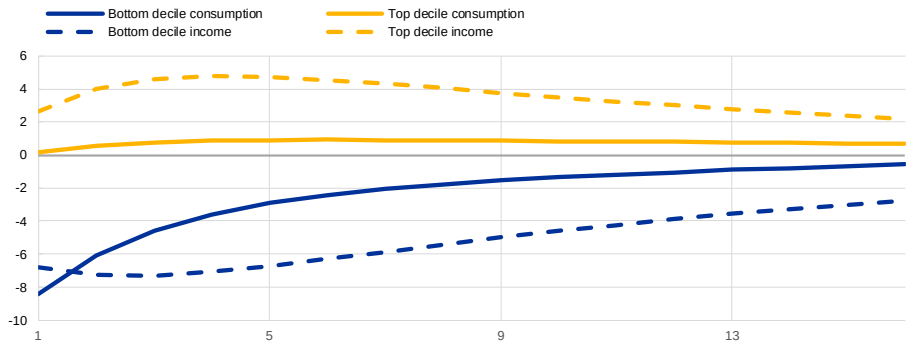
Prepared by Michael Dobrew (ECB)

By disproportionately hurting low-income households, inflationary cost-push shocks have adverse effects not only on aggregate outcomes but also on inequality. Cost-push shocks in standard New Keynesian models introduce a well-known trade-off between output and inflation stabilisation. Heterogeneous agent New Keynesian models additionally make it possible to analyse the distributional consequences of high inflation and show that low-income households are affected most by inflationary shocks.[29] In the face of a price mark-up shock that causes persistently high inflation, firms adjust their production through a combination of both higher prices and lower labour demand. The resulting fall in household labour income arising from lower real wages and lower employment adversely affect consumption and income, as shown in Chart A. This is particularly true for the bottom decile of the income distribution, where a persistent shock raising inflation by 3 percentage points with a half-life of eight quarters leads to a strong initial decline of consumption by around 7%, with strong and persistent effects on income as well. Top-income households in turn benefit from higher inflation due to two main channels. They benefit from higher dividend payments due to rising corporate profits, and also the higher real interest rates that an inflation-fighting central bank engineers to combat the inflationary shock. At the same time, their consumption changes very little, as these households typically have very low marginal propensities to consume (the share of additional income spent on consumption). As for the impact of rising real interest rates, the net wealth of low-income households suffers from increased borrowing costs due to higher real rates, while high-income and wealthy households benefit through higher savings income.

Chart A

Bottom and top decile consumption and income response to an inflationary shock

(y-axis: percentage deviations from steady state; x-axis: quarters)



Source: Authors' calculations based on Dobrew et al. (2021).
Note: Bottom and top decile consumption and income response to a persistent cost-push shock in a heterogeneous agent New Keynesian model with sticky prices and sticky wages.

If monetary policy were to account for the consumption of low-income households, it would nevertheless aim to be more accommodative, allowing yet higher inflation. If monetary policy is concerned about low-income households, it could explicitly take their consumption into

[29] The analysis in this box is based on an extended version of the model studied in Dobrew et al. (2021).

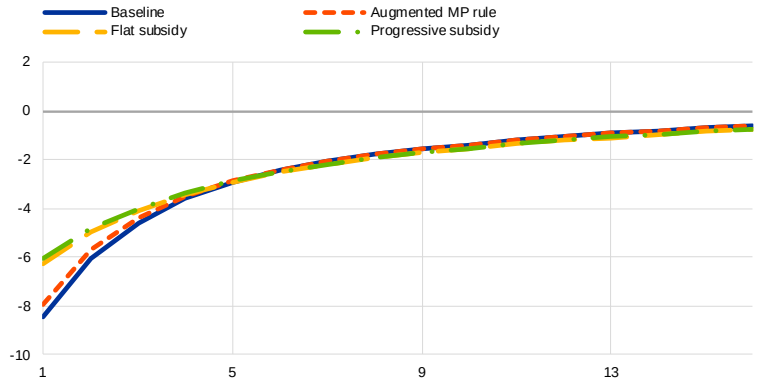
consideration, for example through a Taylor rule that responds to deviations of their consumption from its trend. Instead of reducing inflation through higher nominal rates, such an "augmented monetary policy (MP) rule" would allow higher inflation both when an inflationary shock occurs and over the lifetime of the shock. As shown in Chart B, the rule supports incomes and consumption of low-income households through higher employment, but at the cost of somewhat higher inflation. The additional income accrues to households with high marginal propensities to consume and leads to higher aggregate demand. This allows firms to maintain higher production despite raising their prices and ultimately to pay higher nominal wages which – despite rising inflation – translate into higher real wages and ultimately higher consumption.

Chart B

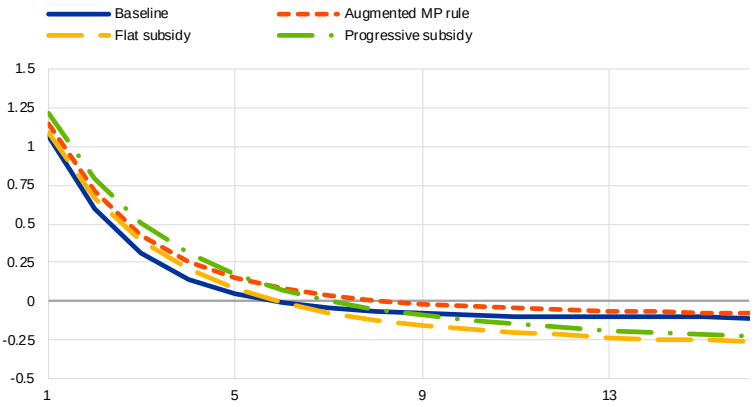
Comparison of bottom decile consumption and nominal interest rate response for different scenarios of monetary and fiscal policy interactions

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)

a) Bottom decile consumption response for different monetary-fiscal scenarios



b) Nominal interest rate response for different monetary-fiscal scenarios



Source: Authors' calculations based on Dobrew et al. (2021).
Notes: Baseline is a standard Taylor rule where fiscal policy runs a balanced budget and has fixed outstanding debt. Flat subsidy is a scenario where fiscal policy subsidises household incomes equally across all incomes in response to an inflationary shock. Progressive subsidy is the same scenario, but the subsidy is inversely proportional to household income. Augmented MP rule is a Taylor rule that also responds to bottom decile consumption deviations from steady state.

Fiscal policies that subsidise household incomes provide more targeted intervention and can therefore more effectively stabilise household consumption while simultaneously creating space for monetary policy to raise rates higher. An alternative to monetary policy accounting for consumption of low-income households is for fiscal policy to subsidise household

income in the face of an inflationary shock. Chart B shows two scenarios where fiscal policy provides either a flat subsidy to all households irrespective of their income or a progressive subsidy, through which low-income households receive a disproportionately higher subsidy whenever their consumption is below trend. In both cases, fiscal policy provides direct additional income, thereby sustaining consumption of households in the face of higher inflation. Since subsidies are more targeted by nature, consumption of low-income households under either subsidy scenario is more effectively stabilised. This is true not only in comparison with the baseline scenario but also with the case of an augmented MP rule, as interest rate changes benefit households that are living hand-to-mouth from their incomes only through indirect general equilibrium effects on wages and employment. Furthermore, by supporting aggregate demand fiscal subsidies generate higher inflation, which creates additional room for monetary policy to raise interest rates. However, this comes at the cost of more inflationary pressure. Despite higher rates and higher inflation, the targeted nature of subsidies benefits low-income households by sustaining their consumption levels.

Box 2 Redistributive consequences of the pandemic policy mix

Prepared by **Michał Brzoza-Brzezina (Narodowy Bank Polski) and Marcin Kolasa (SGH Warsaw School of Economics)**

During the COVID-19 pandemic fiscal authorities faced sharply increasing bills and dramatically falling income. In the euro area these developments resulted in public sector deficits of 7% and 5.1% of GDP respectively in 2020 and 2021.

The fiscal expansion was accommodated by a deep monetary easing. With interest rates close to the effective lower bound, the ECB initiated the Pandemic Emergency Purchase Programme with a total envelope of €1,850 billion for asset purchases. This expansionary policy mix made it possible to finance the necessary expenditure and keep the economy afloat. However, it also likely contributed to higher inflation.

This box offers a preliminary view on the redistributive consequences of the expansion relative to the counterfactual scenario without the stimulus. Fiscal policy distributed income between groups of citizens in a relatively transparent way. The various categories of transfers and expenditure are well documented in Eurostat statistics. What is much less transparent is the redistribution that happened indirectly, due to macroeconomic adjustments and asset price changes. While preventing a collapse in GDP increased incomes of workers and owners of capital, inflation hurt nominal asset holders. As official taxes have not been increased, the latter group is the most likely to have implicitly financed the fiscal expenditures by paying an inflation tax.

To provide a quantitative assessment of these effects, we use a New Keynesian overlapping generations model (Brzoza-Brzezina, Jabłońska, Kolasa and Makarski, 2023), calibrated to reflect the life cycle profiles of key income components and assets of euro area households (cohort averages based on Household Finance and Consumption Survey statistics). Then we simulate the effects of the monetary-fiscal expansion of 2020-21 on the model economy. This exercise allows us not only to look at the income side but, crucially, to assess the financing side of what happened, and how it affected welfare across generations differently. It should be borne in mind that our results document only the consequences of the stimulus, not of the pandemic as a whole, and that our model does not take into account the possibly highly nonlinear effects of the pandemic, which without the stimulus package could have resulted in a serious crisis. Our main results are

summarised in Chart A, which decomposes the net welfare gains into the key channels as viewed from the perspective of an individual household.

During the crisis, fiscal authorities in the euro area countries increased a broad range of transfers. The programmes targeted firms, workers, retirees or simply all vulnerable individuals, irrespective of their age. As a result, the direct contribution of transfers that we show in the figure was strictly positive for all age cohorts, even though older individuals benefited somewhat more. Similarly, and by the very nature of public goods, all types of households benefited from their increased provision when fiscal authorities raised spending on goods and services.

In contrast to these two direct effects, the remaining channels presented in the figure are of an indirect nature as they capture how the policies implemented affected agents through their impact on economic activity and prices, including the returns on assets that households hold. To begin with economic activity, since the monetary-fiscal expansion helped contain an increase in unemployment, it clearly benefited working age cohorts by raising labour income. However, as the chart reveals, this channel (likewise the two described above) did not have any sizeable redistributive consequences.

Instead, the redistribution was mainly shaped by adjustments in returns on real and nominal assets. To understand the former, it is important to remember that households accumulate real assets (mainly housing and equity, the latter also managed by pension funds) up to around the age of retirement, after which they gradually run them down, using the proceeds to support their consumption when labour income is no longer available. Direct fiscal transfers to firms during the crisis, together with the massive monetary accommodation, propped up stock prices, generating large benefits for equity owners (especially those already reducing their stock holdings), and hurting younger households who needed to pay more to accumulate their real assets. This effect generated significant redistribution from younger to older generations.

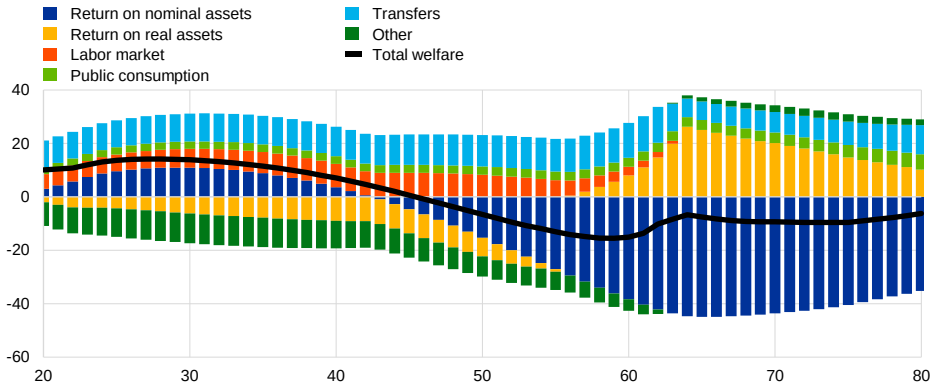
A very different picture is observed when one looks at the consequences of changes in returns on nominal assets. The difference arises from two sources. First, in contrast to real assets, the pandemic policy mix made owners of nominal assets lose due to surprise inflation. Second, the lifetime profile of nominal assets is different, as young households hold these in negative amounts due to mortgages. Nominal asset holdings (including those managed by pension funds) turn positive in the mid-forties, peak in the late sixties and then are slowly run down. Hence, via this channel, the policy mix benefited young households, but massively hurt older generations, who effectively ended up paying most of the inflation tax.

Overall, our analysis suggests that most benefits accrued to the youngest households and the bill was borne mainly by middle-aged and old cohorts. However, as the decomposition of these average gains clearly shows, the rescue programmes launched must have had very unequal effects on individuals within cohorts. In particular, those middle-aged and older households who were keeping most of their wealth in nominal assets ended up paying the highest share of the bill.

Chart A

Welfare redistribution across age cohorts

(y-axis: percent of annual consumption of a given cohort; x-axis: age in 2020)



Source: Authors' calculations based on Brzoza-Brzezina, Jabłońska, Kolasa and Makarski (2023).
Note: The chart shows model-consistent welfare gains expressed as a percentage of annual consumption of a given cohort.

Box 3 Risk sharing and monetary policy transmission

Prepared by **Sebastian Hauptmeier (ECB), Fédéric Holm-Hadulla (ECB) and Théodore Renault (Geneva Graduate Institute)**

The literature on optimal currency areas establishes a clear division of labour in the pursuit of macroeconomic stabilisation objectives. The objective of monetary policy is to limit fluctuations in average macroeconomic outcomes in response to symmetric shocks. Risk sharing, on the other hand, should limit the dispersion in macroeconomic outcomes across the currency union by facilitating a geographically differentiated adjustment to asymmetric shocks.

An central aspect in implementing this division of labour is that the impact of these macroeconomic stabilisation tools may interact. If monetary policy exerts a uniform impact on different members of a currency union, its role in limiting average economic fluctuations is unaffected by the role of risk sharing in limiting economic dispersion. But a growing literature has documented that monetary policy is transmitted unevenly, owing, for example, to differences in economic structures and initial conditions (Eichenbaum et al., 2022, Hauptmeier et al., 2020). This in turn may render the impact of monetary policy dependent on the risk-sharing architecture of a currency union. For instance, if the tax and transfer system systematically reallocates funds from less to more affected regions, the aggregate impact of a monetary policy tightening may be different from a scenario without this type of fiscal risk sharing. Hauptmeier et al. (2022) provide empirical evidence on the relevance and nature of these interactions, based on regionally disaggregated euro area data.

Applying the well-established framework proposed by Asdrubali et al. (1996) to regionally disaggregated data, results show substantial variation in the overall prevalence of intracountry and international risk sharing across euro area countries (Chart A, panel a).[30] The extent to which regional fluctuations in GDP were smoothed by the capital market, credit markets and the public

[30] The analysis relies on NUTS-2 level data, following the Eurostat NUTS classification which subdivides national territories into regions. The use of regional data allows the amount of risk shared within a country (intranational risk sharing) and between countries (international risk sharing) to be captured.

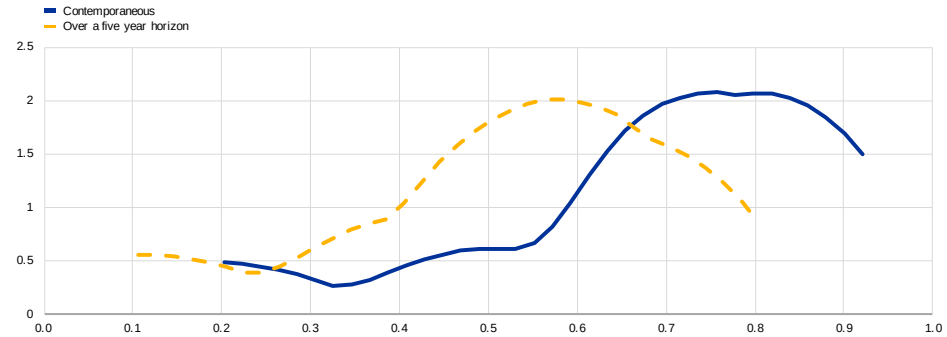
sector varied between 32% and 97% over the period 2000-2018.[31] In terms of strength, the capital channel generally emerges as dominant in smoothing out contemporaneous fluctuations. While the credit market and fiscal channels are found to be weaker, the latter – operating via the public transfer and tax system – has a greater impact over longer horizons. This cross-country variation in risk-sharing intensity and the relative strength of individual channels can be used to empirically assess the implications of inter-regional risk sharing for the real effects of monetary policy.

Chart A

The degree of risk sharing in EMU: regional heterogeneity and time profile

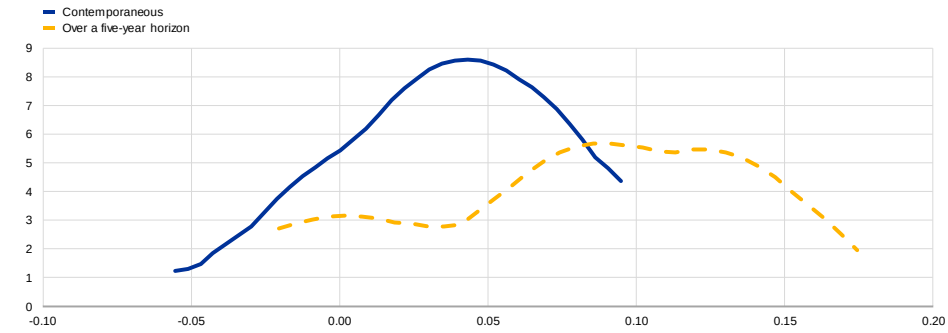
a) Degree of risk sharing through the capital channel

(y-axis: density; x-axis: percentages)



b) Degree of fiscal risk sharing

(y-axis: density; x-axis: percentages)



Source: Hauptmeier, Holm-Hadulla and Renault (2022).
Notes: Panels a) and b) show the cross-country density function of the estimated total degree of risk sharing via the capital and fiscal channels respectively. The solid blue line corresponds to the amount of risk sharing achieved contemporaneously; the dashed yellow line shows risk sharing over a five-year horizon.

Risk sharing plays a key role in shaping the real effects of monetary policy shocks. Panel a) of Chart B shows the estimated impact of a tightening monetary shock on regional output in the euro area, depending on the degree of inter-regional risk sharing.[32] The regional output contraction after a 100 basis point policy rate hike is around 1 percentage point shallower for regions attaining the maximum degree of risk sharing in the sample than for those attaining the minimum degree. Moreover, regions with a high degree of risk sharing are less prone to policy-induced hysteresis (that is, persistent economic effects of interest rate changes); while output in regions with minimum

31 These estimates are not directly comparable with those in Section 3 as they refer to inter-regional risk sharing within countries, while those in Section 3 refer to risk sharing across euro area countries.

32 The analysis relies on local linear estimation techniques (see Jordà, 2005) and includes an interaction term between the monetary policy rate and the amount of risk sharing in the economy. This captures the extent to which the impact of a monetary policy shock varies with the degree of risk sharing (see Hauptmeier, Holm-Hadulla and Renault (2022) for details of the empirical model and estimation techniques).

risk sharing remains around 1.5% below its initial level five years after a monetary policy tightening shock, it recovers fully over this period in regions with maximum risk sharing.

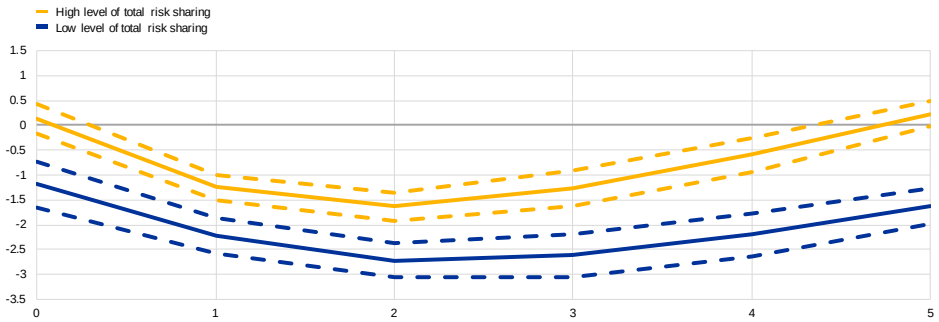
As regards individual channels, fiscal risk sharing proves particularly forceful in determining the persistence of monetary policy effects on poorer regions (Chart B, panel b).[33] For instance, with weak fiscal risk sharing, these regions experience a prolonged output contraction in response to a policy rate hike. With strong fiscal risk sharing, poorer regions not only face a weaker output contraction but are also insulated from such hysteresis effects. For richer regions, the degree of risk sharing has a more limited differential impact on output. These results suggest that fiscal risk sharing can help prevent economic divergence stemming from regional hysteresis.

Chart B

Impact of monetary policy on regional output when risk sharing is high or low

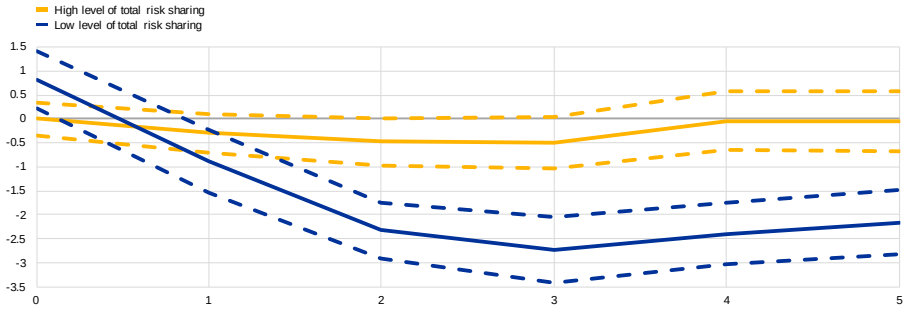
a) Impact on regional output

(y-axis: percentages; x-axis: years)



b) Impact on output in poorer regions

(y-axis: percentages; x-axis: years)



Source: Hauptmeier, Holm-Hadulla and Renault (2022).
Notes: Panel a) shows the impact of a 100 basis point policy rate hike on regional output for low (blue) and high (yellow) levels of total risk sharing for a sample consisting of 155 regions from ten euro area countries over the period 2000-18 at annual frequency. Panel b) shows the impact of a similar shock on regional output in poorer regions (lowest decile of the GDP distribution) for low (blue) and high (yellow) levels of fiscal risk sharing. The x-axis refers to the horizon of the impulse response functions in years.

[33] Poorer regions are defined as the lowest decile of the GDP distribution.

2.3 An assessment based on models with alternative monetary-fiscal policy arrangements

According to economic theory, low and stable inflation can be achieved if monetary and fiscal policy are well coordinated.[34] As shown in Leeper and Leith (2016), macroeconomic stability relies on the joint efforts of monetary and fiscal policy. Both the central bank and the fiscal authority can influence aggregate demand and inflation, and thus are able to either undermine or complement each other's policy objectives. In many dynamic macroeconomic models, the rules that govern the conduct of monetary and fiscal policy conventionally ensure that the central bank actively pursues price stability, while the fiscal authority safeguards long-run public debt sustainability. However, policymakers may face different types of rules or objectives than those typically assumed in standard models. Departures from the conventional monetary-fiscal policy arrangement may significantly affect the central bank's ability to ensure low and stable inflation.

In this section we consider three alternative monetary-fiscal policy arrangements and how they affect the transmission of monetary policy. First, we abandon the assumption that monetary and fiscal policy are always sufficiently geared towards stabilising the price level and public debt respectively, and instead allow for the possibility that policymakers occasionally and temporarily deviate from their conventional policy objectives. This type of "switching" in policy behaviour is not explicitly modelled (that is, not micro-founded), but instead assumed to occur at a probability that is either constant over time or depends endogenously on some state variable (like government debt). Second, we consider the case where monetary and fiscal policy are not always aligned in the sense that, when monetary policy takes a contractionary stance, fiscal policy is expansionary, and vice versa. Finally, rather than considering the conventional fiscal rule of targeting the public debt-to-GDP ratio, we examine the implications of fiscal policy following two alternative operational fiscal rules: the structural balance rule or the expenditure growth rule. For the sake of clarity, we will first describe the characteristics of the conventional monetary-fiscal policy arrangement, referred to as "monetary dominance", and its counterpart, "fiscal dominance".[35]

Under monetary dominance, the central bank pursues an anti-inflation monetary policy, while the fiscal authority commits to ensuring long-run debt sustainability. In a standard macroeconomic model, the policy rule that characterises monetary policy is one relating the nominal policy interest rate to inflation (in terms of deviation from the target) and possibly also output growth (or an output gap). The rule that governs fiscal policy relates the primary balance to public debt (in terms of deviation from its target). Under monetary dominance, the interest rate moves by more than one-to-one with changes in inflation (provided the lower bound on the nominal interest rate is not binding), while the primary balance's

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[34] This section includes contributions from Pierre Aldama (Banque de France), Dennis Bonam (De Nederlandsche Bank), Ginters Bušs (Latvijas Banka), Pascal Jacquinot (ECB), Magali Marx (Banque de France) and Nigel McClung (Suomen Pankki).

[35] See also Section 2.1. In this section, we ignore the possibility of sovereign default and focus on economic environments where debt sustainability can only come from real fiscal revenues or inflation.

sensitivity to changes in government debt is greater than the long-run real interest rate. The former condition (also known as the Taylor Principle) ensures that inflation surges are offset by sufficiently large increases in the real interest rate to dampen aggregate demand. This mechanism ensures that price dynamics are stable and inflation expectations are anchored (provided expectations are rational and forward-looking). The latter condition ensures that, in the long run, government debt grows at a rate below the real interest rate and therefore does not follow an explosive path (see for example Leeper, 1991). Under this arrangement, fiscal policy "passively" follows monetary policy by adjusting the primary balance to ensure debt sustainability for any given price level targeted by the central bank. In general, this implies that a contractionary monetary policy shock that raises public interest expenses and public debt, is followed by a contractionary fiscal policy, and vice versa, ensuring that the government's intertemporal budget constraint equating outstanding public debt with the discounted sum of current and future primary balances remains satisfied.

Under fiscal dominance, debt sustainability is guaranteed by changes in the price level, rather than appropriate adjustments to the primary balance. In terms of policy rules, the primary balance does not respond sufficiently to changes in government debt to ensure long-run debt sustainability. At the same time, the policy rate responds less than one-to-one with inflation. Under specific modelling assumptions (such as the degree of trade openness, the maturity of government debt and the share of foreign ownership of government debt), this policy configuration can ensure debt sustainability due to the effects of monetary and fiscal policy on household wealth. When households, who are the holders of government bonds, observe an increase in government debt not backed by future tax hikes, they will perceive this as an increase in their net wealth. This rise in perceived net wealth fuels consumption, output and inflation until the latter sufficiently erodes the real value of household net wealth.[36] Therefore, under fiscal dominance, the central bank forgoes its price stability objective and allows the price level to move to whatever level is necessary to ensure long-run debt sustainability (Leeper, 1991; Sims, 1994; Woodford, 1998). Because in the euro area the ECB has an explicit mandate to preserve price stability and monetary financing of government debt is prohibited by the Treaty, a regime of fiscal dominance is institutionally ruled out. Nonetheless, it remains worth investigating the theoretical implications of departing from monetary dominance for the ability of monetary policy to stabilise inflation, as agents may worry about the emergence of fiscal dominance, despite policymakers' commitment to maintaining monetary dominance. The next subsection deals with these theoretical implications.

[36] The strength of the wealth channel depends, among other things, on various characteristics of public debt; the maturity structure, the level and the share of debt held by foreign investors, etc. Furthermore, the degree to which the positive wealth effect leads to a rise in domestic inflation depends on the country's trade openness and how much domestic consumption goes on imported foreign goods.

2.3.1 Departures from monetary dominance

From a theoretical perspective, a monetary tightening shock can lead to a rise in inflation if there is a sufficiently high probability of moving to a regime of fiscal dominance. This theoretical result can be illustrated using a stylised (calibrated) DSGE model (e.g. Leeper and Leith, 2016) featuring the monetary and fiscal policy rules described previously, and assuming a fixed probability that the economy occasionally switches between the monetary dominance and fiscal dominance regimes. Chart 5 shows the responses to a temporary monetary tightening shock as predicted by the model, assuming the economy is operating under monetary dominance at the time the shock occurs. Although the probability of staying under the monetary dominance regime is set relatively high (0.94, to be precise), there is a small chance that a switch to fiscal dominance occurs. As a result, the monetary contraction may eventually lead to a rise in inflation (the solid lines). Intuitively, the monetary tightening leads to an increase in the government's debt servicing costs, raising government debt. Since households expect a switch to the fiscal dominance regime, in which the rise in government debt is not fully backed by future tax hikes (even though the probability is very small), they perceive the rise in debt as an increase in their net wealth. This induces them to raise their consumption, which in turn fuels inflation.[37] The rise in inflation prompts the central bank to tighten monetary policy again, further raising perceived net wealth, consumption and inflation.[38] Explosive dynamics of this sort may have occurred in France between the 1950s and 1990s; an estimated regime-switching DSGE model suggests the fiscal dominance regime may have prevailed during that period (see Box 4). The evidence further points to a switch to monetary dominance in the period thereafter, coinciding with EMU convergence and a strengthening of central bank independence. This result is in line with other studies showing that monetary dominance has prevailed in the euro area since the adoption of the common currency, even during episodes of strong public debt growth such as the European sovereign debt crisis and the pandemic. For example, Box 17 in Debrun et al. (2021) shows that market-based measures of long-run inflation expectations did not respond positively to increases in fiscal burden in the euro area during these two episodes, despite monetary policy being highly accommodative at the time. These results suggest that markets expect debt sustainability issues to be resolved through fiscal consolidation rather than higher inflation – which is consistent with the monetary dominance regime as ensured by the institutional framework of the EMU. Similarly, Brandao-Marques et al. (2023) show that public debt surprises do not have a significant effect on long-term inflation expectations in advanced economies with inflation targeting regimes. However, there are some who are argue that the prevalence of monetary dominance in the euro area may currently be challenged

37 This result is reminiscent of the "stepping on a rake" mechanism described in Sims (2011).

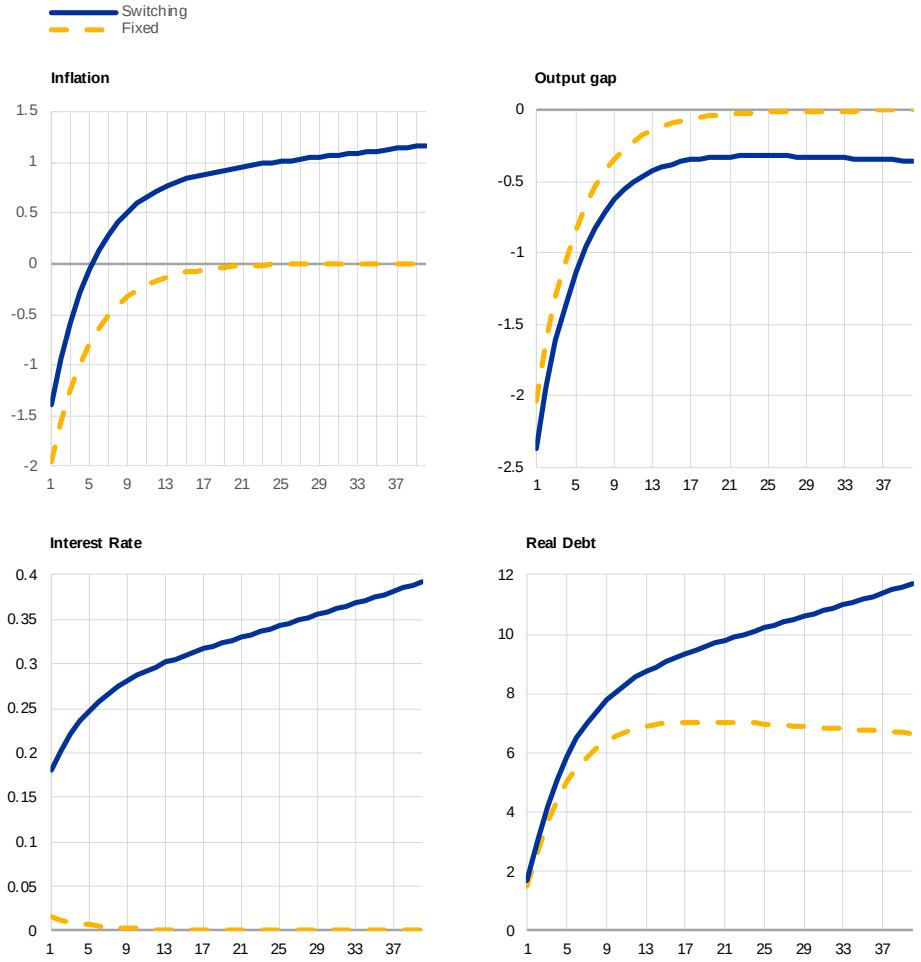
38 Despite the positive wealth effects arising from the probability of moving from monetary dominance to fiscal dominance and the corresponding upward pressure on consumption that these generate, we still observe a decline in the output gap. This is because there remains a large probability of the economy continuing under the monetary dominance regime, with the central bank actively combating the rise in inflation by means of interest rate hikes to lower consumption and hence the output gap. Note too that monetary tightening generates debt servicing costs which more than offset the debt-stabilising effects of higher inflation. The rise in inflation in the medium run under switching depicted in Chart 7 is therefore not sufficient to stabilise real debt.

and that risks of fiscal dominance have increased (see for example Benigno et al., 2023; Brunnermeier, 2023).

Chart 5

Responses to a monetary tightening shock, starting from monetary dominance

(y-axes: percentage deviations from steady state; x-axes: quarters)



Source: Authors' calculations.
Notes: The y-axes show percentage deviations from steady state (e.g. a value of 1 corresponds to a 1 percent deviation from steady state). Inflation is depicted as annualised percentage point deviations from the zero-inflation target.

For a monetary tightening shock to lower inflation, fiscal dominance must be ruled out. The dashed lines in Chart 5 show the responses to the same monetary tightening shock, yet now assuming there is no possibility of switching to the fiscal dominance regime. In this case, inflation falls in response to the shock on impact, as with switching, yet remains below its initial level in all subsequent periods. Since the rise in government debt following the monetary contraction is expected to be offset by increases in future taxes, households perceive a decline in their net wealth. This causes them to cut their consumption, which in turn leads to a fall in inflation. Therefore, in order to engineer a decline in inflation, monetary tightening must be accompanied by the "right type" of fiscal policy.

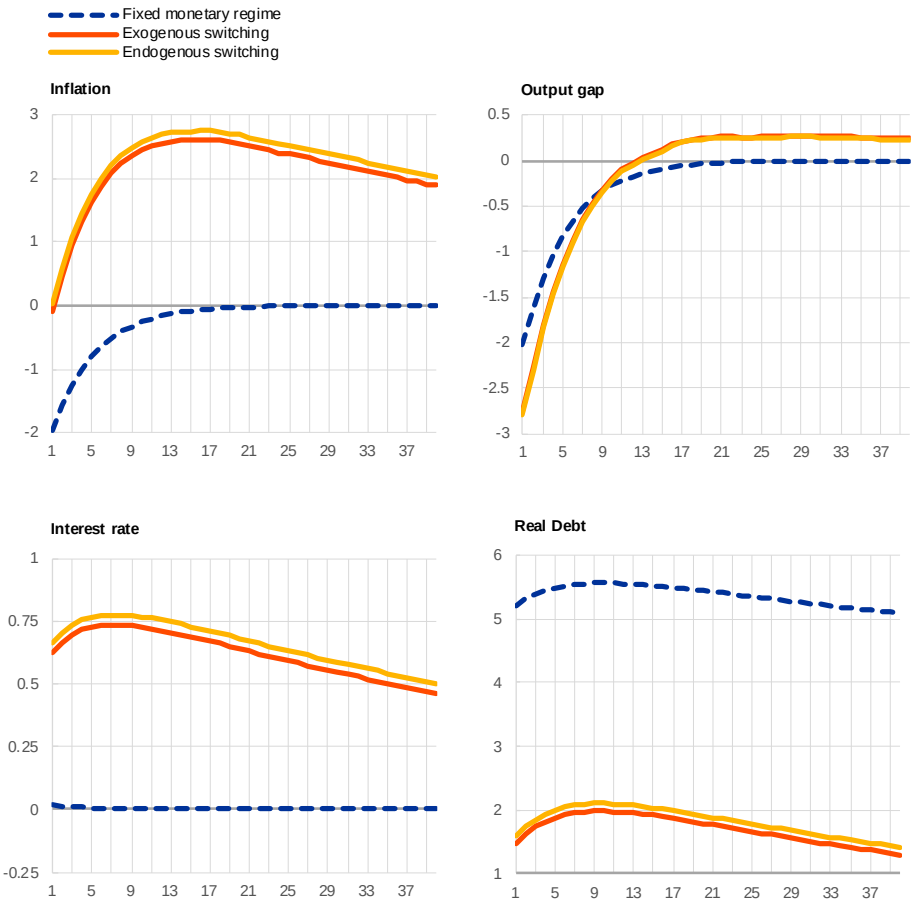
A monetary tightening shock may have stronger inflationary effects when the probability of switching to fiscal dominance depends positively on the level of

government debt. Large and persistent increases in fiscal liabilities may erode the fiscal authority's credibility with regards its ability to stabilise public debt and could therefore increase the risk of fiscal dominance as perceived by households. Chart 6 shows the implications of such an endogenous probability of switching to fiscal dominance for the impact of a monetary tightening shock. Specifically, it is assumed that this probability depends positively on the level of government debt.[39] (Note that this exercise is different from what was shown in Chart 5, where the responses were conditional on remaining in the monetary dominance regime.) Under this assumption, the rise in government debt that results from the monetary tightening shock now raises the probability of fiscal dominance. Consequently, the wealth effect of monetary and fiscal policy is amplified and generates stronger upward pressures on inflation than when transition probabilities are constant and exogenous.

Chart 6

Responses to a monetary tightening shock, starting from monetary dominance and assuming endogenous switching

(y-axes: percentage deviations from steady state; x-axes: quarters)



Source: Authors' calculations.
Note: The y-axes show percentage deviations from steady state (e.g. a value of 1 corresponds to a 1 percent deviation from steady state). Inflation is depicted as annualised percentage point deviations from the zero-inflation target.

[39] In principle, the probability of transitioning to the fiscal dominance regime could depend negatively or not at all on the debt-to-GDP ratio. The question of whether and how this probability depends on government indebtedness (or other variables) is an empirical question not examined here.

Box 4 Monetary and fiscal dominance: the case of France

Prepared by Othman Bouabdallah (ECB), Pascal Jacquinot (ECB) and Valeria Patella (Sapienza University Rome)

Past crisis episodes in the euro area have rekindled interest in monetary-fiscal policy interactions. Renewed emphasis has been put on the macroeconomic consequences of beliefs that primary balances are insufficient to contain the development of government debt and how such beliefs affect the central bank's ability to control inflation. In this box we present empirical evidence on recurrent policy regimes in France and provide counterfactual scenarios on what agents believe about regime changes in the future.

We estimate a New Keynesian model with switching between monetary and fiscal dominance regimes. These regimes are characterised by different policy rules and the aggressiveness with which policy instruments are adjusted to meet certain objectives. More specifically, monetary policy is described by a rule relating the nominal policy interest rate to inflation, while the fiscal policy rule relates taxes to public debt. Under monetary (fiscal) dominance, the interest rate moves by more (less) than one-to-one with inflation, while taxes rise by more (less) than net real interest rate expenses. The two regimes are recurrent, and when forming their expectations agents take into account the probabilistic distribution of future regime changes. Since policy regimes may be persistent and prevail for many years, we use a relatively long-sample dataset covering the period 1955 to 2019. The model accounts for France's adoption of the euro and monetary policy being constrained by the ELB on the nominal policy interest rate since 2009.

The estimated model suggests that France operated under a regime of fiscal dominance up to the early 1990s and transitioned to a regime of monetary dominance thereafter. The shift coincided with EMU convergence and a strengthening of central bank independence. In the latter part of the sample, when the ELB became binding, our model suggests that a constrained monetary policy used non-conventional tools to retain its ability to stabilise inflation around its target, while the fiscal authority disregarded debt sustainability issues. This regime can be considered a case of policy conflict, with the two authorities not coordinating their respective policies properly. Bianchi and Melosi (2019) show that a policy conflict like this can cause the economy to enter a vicious spiral of rising inflation and public debt, and can thus only be a temporary situation if a stable and unique equilibrium is to be ensured (see also Sims, 2011; Bianchi and Ilut, 2017).

A positive shock to long-term debt-financed expenditure has a much stronger impact on GDP under fiscal dominance than under monetary dominance. Following the shock, inflation, GDP and the nominal interest rate rise, regardless of the policy regime that prevailed at the time of the shock (Chart A). However, because of a weaker response in monetary policy to the rise in inflation under fiscal dominance (the solid lines), the response in the interest rate is more muted than under monetary dominance (the dashed lines). This allows the expenditure shock to have a stronger effect on GDP, which in turn helps reduce the government debt-to-GDP ratio. The amplification also stems from households expecting that the fiscal expansion will not be met by future fiscal adjustments, which thereby raises their perceived net wealth and further stimulates aggregate demand. However, as real interest payments on government debt fall, net household wealth slowly declines, explaining why the bout of inflation is less persistent under fiscal dominance than monetary dominance. Although, as this simulation shows, the fiscal dominance regime can render fiscal stimulus measures more effective compared with the monetary dominance regime, there are also risks associated with the prevalence of fiscal dominance in the form of greater inflation surges and a de-anchoring of inflation expectations that reduces welfare. The greater the

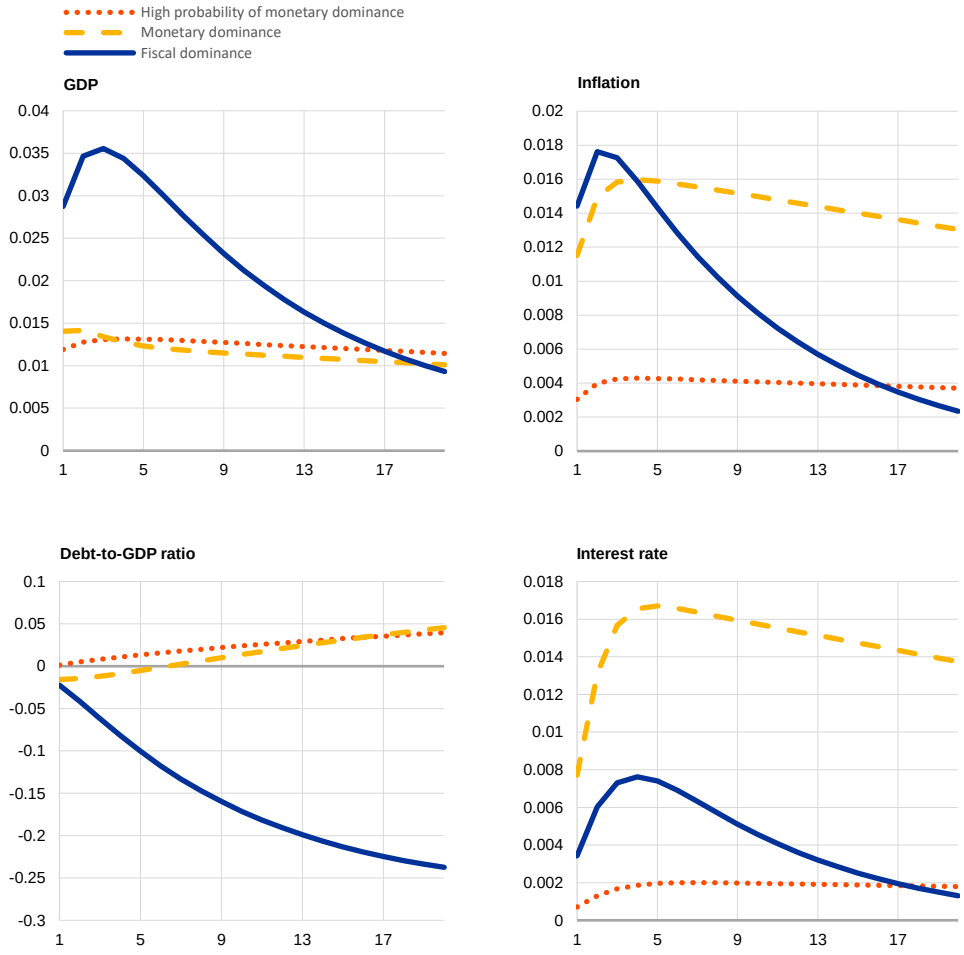
expected duration of the fiscal dominance regime and the weaker the government's commitment to public debt sustainability in times of monetary dominance, the higher these risks are.

The propagation mechanism of the shock depends strongly on agents' beliefs about the persistence of the prevailing regime. To illustrate this, we perform a counterfactual scenario in which the monetary dominance regime is perceived by agents as more persistent. Moreover, we now assume that, once the fiscal dominance regime prevails, agents expect the economy to quickly return to the monetary dominance regime (the dotted lines). Conditional on starting under fiscal dominance, the expenditure shock now has a much more muted effect on inflation, GDP and the interest rate. Intuitively, when agents expect the monetary dominance regime to return tomorrow with a high probability, they behave as if they were already operating under that regime today. Consequently, agents internalise the future aggressively anti-inflation monetary policy stance that characterises the monetary dominance regime, containing the expansionary impact of the expenditure shock on aggregate demand. This underscores the importance of credible policy announcements to anchor expectations about the future policy stance.

Chart A

Responses to a long-term expenditure shock in France

(y-axes: percentage deviations from steady state; x-axes: quarters)



Source: Bouabdallah et al. (2023).

2.3.2 Monetary policy under expansionary and contractionary fiscal policy

The effects of monetary policy may also depend on whether or not monetary and fiscal policy are working in the same direction. Despite empirical evidence showing that the euro area has always operated under a regime of monetary dominance (and no risks of fiscal dominance have ever emerged), it did occasionally experience episodes during which monetary and fiscal policy moved in opposite directions. For example, in the aftermath of the sovereign debt crisis, the ECB pursued an expansionary monetary policy in an attempt to stabilise low inflation around the inflation target. However, during the same period, some euro area governments were engaged in large fiscal consolidations in an effort to reduce public debt. In contrast, during the more acute years of the COVID-19 pandemic, both monetary and fiscal policy were expansionary. In this period, the economic recovery was swift.

When monetary and fiscal policy move in opposite directions, it may be more difficult for the central bank to lower inflation by increasing the interest rate. There are at least two reasons for this. The first and more straightforward one is that a monetary policy shock can be either offset or amplified by a simultaneous fiscal shock that affects aggregate demand and inflation through the standard New Keynesian multiplier channel. The second reason arises from the impact of monetary and fiscal policy on household wealth. When the central bank raises the interest rate, it generates both an intertemporal substitution effect and a wealth effect. On the one hand, intertemporal substitution leads to a decline in consumption, since the higher interest rate makes it more attractive to increase savings. On the other hand, because the monetary tightening also raises the interest rate receipts on savings, households experience an increase in their wealth which allows them to raise consumption. Whether this positive wealth effect is sufficient to dominate the intertemporal substitution effect depends on many factors. For instance, the wealth effect is likely stronger when households have lots of savings, the marginal propensity to save for a given interest rate hike is very low and the duration of households' assets is relatively short, so the negative revaluation effects of a higher interest rate that would lead to a decline in net wealth are small. Caramp and Silva (2023) show in a theoretical model that the wealth effect also depends on the behaviour of fiscal policy: if the government responds to the interest rate hike by raising taxes, it would offset the positive wealth effect. But if fiscal policy is not sufficiently contractionary, or even expansionary, the wealth effect is more likely to be positive and raise consumption (see also Leeper, 2016).

Empirical evidence shows that a monetary tightening shock lowers inflation if fiscal policy is also contractionary, while when fiscal policy is expansionary the response of inflation may be smaller. In particular, Kloosterman et al. (2022) use a panel smooth transition local projection model and quarterly data for ten euro area countries to estimate the effects of monetary policy shocks across two fiscal

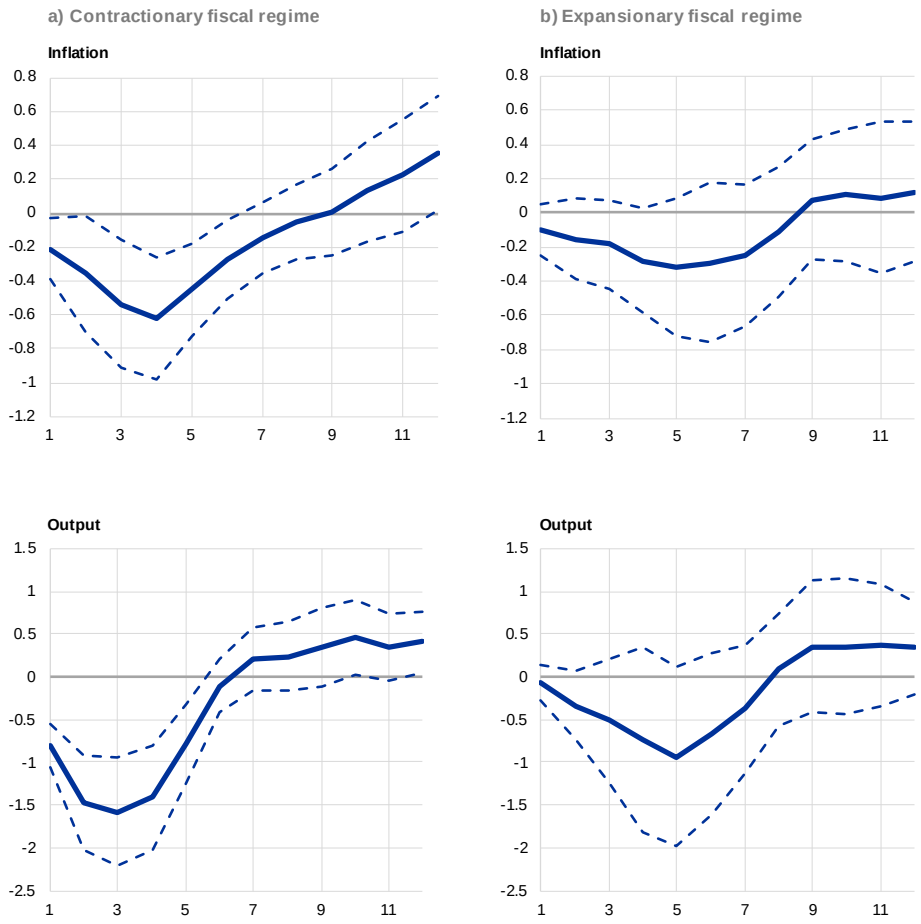
regimes.[40] These are characterised by the change in the cyclically adjusted primary balance: positive changes indicate a contractionary fiscal regime and vice versa. A logistic function is used to retrieve the probability that these two regimes prevailed in each period and for each country individually. The resulting regime indicator is then used to assess the impact of the monetary policy shock conditional on being in either regime. Chart 7 plots the estimated responses to a contractionary monetary policy shock, conditional on being in the contractionary fiscal regime (the left-hand column) and the expansionary fiscal regime (the right-hand column). When the shock occurs in the contractionary fiscal regime, the monetary tightening shock is followed by the expected decline in inflation and output growth. However, conditional on being in the expansionary fiscal regime, the responses in inflation and output growth are much smaller. While these findings depend on the empirical framework and several assumptions (most notably the homogeneity of responses to the common monetary policy shock across the euro area countries, which is not supported by empirical evidence), they nevertheless underline the importance of the fiscal policy stance for the effectiveness of monetary policy.

[40] The data covers the period from the first quarter of 1999 to the fourth quarter of 2019. The panel consists of the following ten countries in the euro area: Belgium, Germany, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland. The monetary policy shocks are taken from Jarociński and Karadi (2020), who exploit high-frequency co-movements of interest rates and stock prices around policy announcements to identify exogenous monetary policy shocks.

Chart 7

Responses to a contractionary monetary policy shock

(y-axes: percentage points; x-axes: quarters)



Source: Kloosterman et al. (2022).
Notes: The figure shows the estimated impulse response functions to a one standard deviation contractionary monetary policy shock, conditional on being in the contractionary (the left-hand column) and expansionary (right-hand column) fiscal regime. The dashed lines reflect the 90% confidence interval based on Driscoll-Kraay standard errors.

2.3.3 The role of alternative fiscal rules

The extent to which fiscal policy either amplifies or dampens the effects of monetary policy can also depend on the type of rules constraining fiscal policy. Governments typically face a set of fiscal rules which restrict the size of the budget, and are generally meant to minimise the risk of unsustainable debt dynamics and ensure monetary dominance. Such rules are particularly relevant within the euro area, as debt sustainability issues may have cross-border effects and could hamper the transmission of the common monetary policy; furthermore, member states of a monetary union may have a deficit bias if they do not sufficiently internalise the impact their national fiscal policies have on union-wide macroeconomic conditions. The EU framework for fiscal policies provides two fiscal criteria: a lower limit on the government deficit and an upper limit on government debt (both as a percentage of GDP). The operational fiscal rules (the structural balance rule and the expenditure

growth rule) help ensure convergence with those fiscal criteria. The way operational fiscal rules constrain fiscal policy can be relevant for monetary policy, as they affect how fiscal policy adjusts in response to a monetary policy shock and hence the ultimate responses in aggregate demand and inflation. In this section, we examine the effects of monetary policy shocks under these alternative operational fiscal rules. Throughout, we assume that monetary dominance prevails.

When the government faces a structural balance rule, a monetary tightening shock provokes a fiscal tightening that amplifies the effect of the shock. Using the DSGE model from Bušs et al. (2021), which features a rich fiscal block, the responses to a monetary tightening shock are simulated under alternative operational fiscal rules (Chart 8). The structural balance rule puts a lower limit on the size of the structural balance, while the expenditure growth rule limits the growth rate in primary government expenditure. Under both rules, the government adjusts its consumption expenditure to meet the corresponding targets.[41] Under the structural balance rule, fiscal policy will mostly[42] be affected through the debt servicing channel: the higher interest rate leads to a deterioration of the structural balance (with respect to its target), which prompts the government to tighten fiscal policy and cut expenditure and/or raise taxes.[43] Therefore, under a structural balance rule, the effects of a monetary tightening shock are amplified by the resulting fiscal contraction.

Under the expenditure growth rule, the fiscal reaction to a monetary shock is more muted. The growth limit applies to government expenditures excluding interest payments; therefore fiscal policy will not directly be affected by the debt servicing channel. Moreover, since the targeted growth rate in government expenditure is independent from cyclical changes in tax revenues, fiscal policy is not directly affected by the revenue shortfall channel under this rule. As a result, there is almost no endogenous fiscal response to the monetary tightening shock under the

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41 Technically, the structural balance rule used in the simulation is expressed as follows: $\ln(x_t) = (1-\rho_x)\ln(x) + \rho_x \ln(x_{t-1}) + (1-\rho_x)\theta_{x,sdy}\{sdy_t - [dy - \phi_{x,d}(D_{g,t} - \overline{dgy})]\}$, where x_t denotes public consumption expenditures. The parameter $\theta_{x,sdy}$ governs the tightness of the structural balance rule with respect to the structural balance target dy, ρ_x controls the persistence of government expenditure adjustments and $\phi_{x,d}$ determines the strength of the correction of the structural balance target with respect to the debt-to-GDP ratio, $D_{g,t}$, in deviation from the debt target, $\overline{dgy}$. Similarly, the expenditure growth rule is given by: $\ln(x_t) = (1-\rho_x)\ln(x) + \rho_x \ln(x_{t-1}) + (1-\rho_x)\theta_{x,gg}\{gg_t - [\overline{gg}_t - \phi_{x,d}(D_{g,t} - \overline{dgy})]\}$, where gg_t is the quarter-on-quarter growth rate in modified government expenditure (i.e. excluding the cyclical component of unemployment benefits, interest payments on public debt and public investment expenditures in deviation from its past 4-year average) and $\overline{gg}_t$ is the ten-year symmetric average of the unit-root technology growth rate.

42 The structural balance rule should in principle be unaffected by the revenue shortfall channel, as the structural balance corrects the budget balance for cyclical changes in the output gap. However, this correction may not fully capture shock-specific revenue elasticities, developments in profit-related taxes due to leads and lags in tax collection, consumption switching over the business cycle, structural changes in the economy, and other factors (see e.g. Morris et al., 2009). Moreover, the estimate of the structural balance rule is subject to measurement errors in the real-time estimate of the output gap. Therefore, fiscal policy would still be sensitive to the revenue shortfall channel when the government faces a structural balance rule.

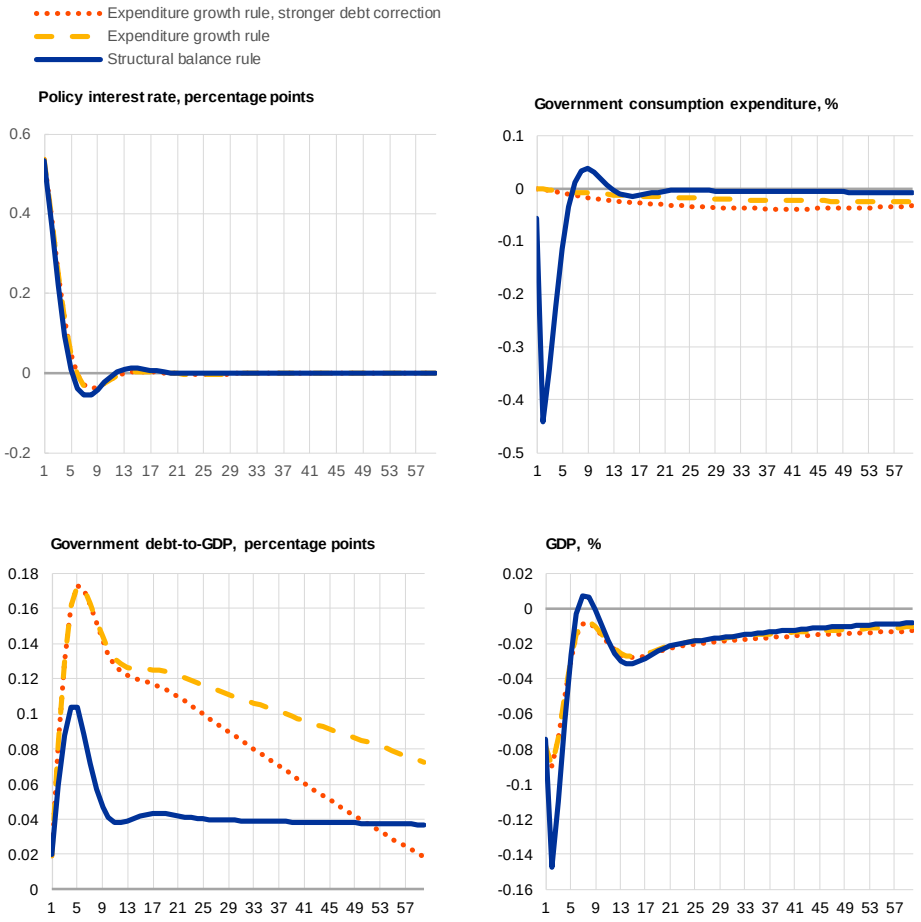
43 In the model, the government is assumed to only issue short-term government bonds. In reality, governments typically issue bonds with a longer maturity. In that case, the fiscal response to the interest rate hike under the structural balance rule would be more gradual than is predicted by the model.

expenditure growth rule,[44] and the contraction in output is smaller than under the structural balance rule. Note that the build-up of government debt is stronger under the expenditure growth rule than the structural balance rule in the face of a monetary policy tightening shock. However, the convergence of government debt to its target under the expenditure growth rule can be facilitated by strengthening the role of the debt-correction term inherent in the expenditure growth rule (Chart 8).[45]

Chart 8

Responses to a monetary tightening shock under different fiscal rules

(y-axes: percentage/percentage point deviations; x-axes: quarters)



Source: Authors' calculation based on Bušs, Grüning and Tkačevs (2021).
Note: Simulations assume that monetary dominance prevails.

[44] There is a minor response due to the debt-to-GDP anchor in the expenditure growth rule, as without the debt correction term the expenditure growth rule does not ensure public debt sustainability.

[45] In the simulation with faster debt convergence, the debt-correction term is made twice as strong. Absent the expenditure growth targeting, this would imply speeding up the rate of annual debt-to-GDP gap correction from 1/25 to 2/25. However, the presence of the expenditure growth target alters the actual rate of debt convergence in a non-linear way (see Bušs et al., 2021).

2.4 Model-based considerations for quantitative easing and quantitative tightening in a fiscally heterogenous monetary union

Large-scale asset purchases can be a powerful monetary policy tool, especially in a heterogeneous monetary union in the presence of sovereign risk.[46] In environments characterised by low inflation and low real rates, QE policies, like the APP initiated in the euro area in 2014 have been extensively used by major central banks since the great financial crisis. The literature generally concludes that these policies, typically complemented by other non-standard monetary policy measures, have proved effective in supporting price stability and stimulating economic activity (Altavilla et al., 2021). Generally, QE eases financial conditions through a reduction of duration risk that flattens the yield curve, thereby compressing long-term interest rates (Eser et al., 2019). Moreover, a central bank may resort to purchases of sovereign debt securities to ensure the stability of the financial system, in order to preserve the transmission of monetary policy, offering an important equilibrium-selection mechanism in the presence of potentially self-fulfilling multiple equilibria (Corsetti and Dedola, 2016). By issuing monetary liabilities in exchange for public debt securities, central banks can help coordinate expectations away from bad equilibria. This dimension of central bank asset purchases may be particularly relevant, but also politically challenging, in a heterogeneous monetary union with sovereign risk at country level (Corsetti et al., 2019).

Since inflation surged in 2021 central banks have reduced policy accommodation by increasing policy rates and undoing some of the QE measures, mindful of the need to preserve smooth transmission of monetary policy. Given that unwinding such policies can pose challenges for the smooth transmission of monetary policy, central banks intend the run-down of their balance sheet to interfere as little as possible with their policy stance. The ability to do so likely rests on the premise that the effect of QT policies (or balance sheet normalisation policies) are not necessarily symmetrical to QE policies. On the one hand, QT may have a more limited impact than QE, because some of the channels that were found to be important in explaining the effects of QE seem to be smaller or inexistent. QE is generally perceived to have large announcement effects when policy interest rates are at their ELB, as it can reinforce forward guidance and reduce interest rate expectations by signalling a commitment to maintain low policy rates for a longer period. This effect is likely less important when the policy stance can be tightened by raising interest rates and QT takes place in a gradual and predictable way (Bullard, 2019, and Lane, 2022). On the other hand, the liquidity effect of QT may be more pronounced, because interest rates are typically no longer closely anchored to the lower bound, as was apparently the case in the normalisation of the Fed's balance sheet between 2017 and 2019 (Smith and Valcarcel, 2023). In addition, in a heterogeneous monetary union it is also important to anticipate the

[46] This section includes contributions from José Cardoso da Costa (Banco de Portugal), Sandra Gomes (Banco de Portugal) and the authors of boxes.

potential side effects QT may have on financial stability, specifically the possibility of fragmentation risks resurfacing, which could also affect the conduct of fiscal policy.

Monetary policy normalisation can pose challenges not only to the transmission of monetary policy itself, but also to the interplay between price stability and financial stability, potentially reinforced by fiscal concerns about the sustainability of sovereign debt. In an environment where central banks need to increase policy rates rapidly by a significant amount to curb inflation, the goals of price stability and financial stability need to be carefully pondered. The ECB's monetary policy strategy acknowledges that financial stability is a precondition to price stability and vice versa. In view of the price stability risks generated by financial crises, there is a strong case for taking financial stability considerations into account in monetary policy deliberations. Moreover, monetary policy, financial stability and fiscal considerations often interact with each other. For example, under acute disorderly financial market stress, purchases of sovereign debt can be a powerful instrument to protect and, where needed, to restore adequate monetary policy transmission. In the multi-country setting of the euro area, smooth transmission of the monetary policy stance across all member countries is particularly relevant, as the singleness of monetary policy is a precondition for price stability. Over the years, these insights have been instrumental in the design of various facilities, recently including the PEPP (launched in 2020), which complements a QE-type monetary policy stance function with a market stabilisation function and temporarily offers more flexibility than the APP.

Designing central bank purchases of sovereign debt is challenging; their effectiveness requires a distinction between non-fundamental and fundamental fiscal vulnerabilities (Blanchard, 2022). In a monetary union without a fiscal union this distinction is particularly relevant, reflecting the coexistence of a single monetary policy decided at union level, and many fiscal policies predominantly decided at the level of member countries (Uhlig, 2003). Reflecting the complexity of interactions in such environment, there is scope for central bank backstops which under exceptional circumstances allow purchases of sovereign debt that are conceptually distinct from QE-type facilities and aim at dealing with episodes of instability which are not driven by fundamentals. Backstops require different and stronger safeguards, with design features which depend on the nature of the vulnerabilities to be addressed. Examples in the euro area include outright monetary transactions (OMTs, launched in 2012) and the transmission protection instrument (TPI, launched in 2022). While OMTs would be subject to conditionality and involve the European Stability Mechanism, the TPI would require i) compliance with the EU fiscal framework; ii) the absence of severe macroeconomic imbalances; iii) fiscal sustainability; and iv) sound and sustainable macroeconomic policies.

At a conceptual level, the literature on interactions between the normalisation of monetary policy, **heterogeneous fiscal policies and financial stability in a monetary union is scarce.** Box 5 offers a framework for conceptualising the impact of alternative designs of QE policies in a fiscally incomplete monetary union in which the central bank cannot buy or sell a commonly shared risk-free sovereign bond and the sovereign debt of member states may not be risk-free, assuming fundamental

weaknesses. The idea is that effective design can support the central bank's price stability objective and at the same time indirectly reduce the likelihood of sovereign default.

Box 5 Design aspects of QE and QT in a fiscally incomplete monetary union

Prepared by Leopold von Thadden (ECB)

Central banks with responsibility for a monetary union composed of heterogenous member states with asymmetric levels of sovereign debt face specific challenges when designing monetary policy. This box looks at challenges which arise when the central bank decides to temporarily conduct large-scale purchases of sovereign debt ("QE"), motivated by an environment of union-wide low inflation and structurally low interest rates near their effective lower bound. Institutionally, it is assumed that the fiscal architecture of the monetary union is incomplete – that is, the central bank cannot intervene with open market operations in a commonly shared risk-free sovereign bond. It is further assumed that the sovereign debt of member states may not be risk-free, reflecting imperfections in the governance and coordination of fiscal policies of member states.[47] In such a constellation, QE is a multi-dimensional and potentially powerful instrument that affects both monetary and fiscal policy outcomes. By nature, it involves a multi-country setting and many parameters that need to be carefully chosen, extending design choices that are known from the literature on QE in stand-alone economies with a single monetary and a single fiscal policy.

This box sketches findings from a model-based comparison of QE designs in a fiscally incomplete monetary union. Drawing on ongoing work by von Thadden (2023), the idea is that an effective QE design should first and foremost prevent shortfalls of union-wide inflation relative to the central bank's inflation target. However, it can also help to contain unwelcome outcomes of fiscal policy. In a sense, an effective QE design can create a sort of "divine coincidence" – supporting the price stability objective of the central bank and at the same time indirectly reducing the likelihood of debt overhangs contributing to sovereign default. However, this coincidence is state-contingent, since the activation of QE depends on the path of union-wide inflation. Conceptually, this establishes a link to QT, describing a reversal of QE operations under a normalisation of monetary policy.

The project uses a modelling structure which is an extension of the monetary union model of Gourinchas et al. (2020). This reference model considers two countries, a core country with low legacy debt which can issue risk-free bonds and a peripheral country with high legacy debt issuing risky bonds. The model allows for two periods and is designed to capture first-order elements of strategic interactions in a tractable manner. To capture the riskiness of the periphery's debt, the output of the peripheral country in period two is assumed to be stochastic. When output is high, the periphery's debt will be repaid; when it is sufficiently low, the country may decide to default. In period two, the key determinants of the threshold value of the periphery's output output above which debt will always be repaid are the level of legacy debt, the level of default costs, the recovery value of the bonds under default, and the share of bonds held by foreign investors. If this latter figure is sufficiently large, it may create a strategic incentive to not repay bonds in full, known from

[47] For a complementary analysis on design aspects of QE in fiscally sound monetary unions, see Bletzinger and von Thadden (2021). This paper uses the assumption that sovereign debt of all member countries is always risk-free at the going price level.

open-economy models. The question pursued by Gourinchas et al. (2020) is how default incentives can be mitigated in such an intertemporal set-up, focusing mostly on the role of discretionary fiscal transfers in the second period.

The monetary extension of the reference model considered in this box assumes that in either country real balances can be held alongside sovereign bonds in household portfolios, motivated by the special liquidity services offered by money. In particular, when hit by a symmetric liquidity preference shock, households in both countries want to rebalance their portfolios towards liquidity provided by the central bank and away from the sovereign debt of the two countries. Such shock can activate symmetric central bank QE purchases. The analysis explores how three distinct QE designs, characterised by different treatments of sovereign bonds held by the central bank, may indirectly affect the occurrence of default in the second period. The first design assumes that central bank purchases rank pari passu and have no risk sharing; the second assumes that central bank purchases rank pari passu and are subject to risk sharing; the third assumes that central bank holdings are senior to privately held debt.[48]

Comparing the three designs yields two interesting results. First, buying back ("re-nationalising") foreign-held bonds by means of central bank QE purchases reduces default incentives. Second, the first design, characterised by i) pari passu ranking and ii) no risk sharing, tends to be the most effective at reducing most effectively occurrences of default at given debt levels. This reflects the fact that the first design maintains the separation of government budget constraints, while under the second design the risk sharing of bonds held by the central bank creates a link between otherwise separate budget constraints. The third design can increase default incentives as it reduces the recovery funds available for a restructuring of privately held bonds.

Future work could explore further extensions. First, the analysis so far covers only fundamental aspects of sovereign risk. Non-fundamental aspects of sovereign risk and the scope of multiple equilibria where relevant, for example, for the dynamics of rollover crises, are not yet addressed. Second, a deeper analysis could address how default costs perceived by governments are likely to vary, depending on whether foreign held debt is held i) inside or outside the monetary union and ii) by private or public investors. Third, the analysis could be extended to cover aspects of optimal debt issuance in the first period in a fully intertemporal context.

As as policy implications are concerned, it is important to remember that the "divine coincidence" disappears if the economy returns to a normal inflation environment which no longer offers a justification for stimulus through QE. In this situation the stock of central bank QE holdings of sovereign debt can be expected to decline over time. However, the magnitude and the speed of the decline will be influenced by various factors, including the ability of the private sector to re-absorb the QE portfolio. For this process to be smooth, governments need to show credible fiscal commitments to maintaining government debt on a sustainable path. Moreover, any improvements in output growth will facilitate this task. Finally, it should be emphasised that the channels addressed in this box naturally lose relevance if the debt levels of member countries become more similar and the fiscal architecture becomes more complete, as this would unburden monetary policy and support risk-sharing arrangements at the private and public level.

[48] The central bank is owned by the two governments. Under risk sharing, central bank income and losses on QE bonds issued in the core and periphery are shared by the two governments; with no risk sharing these streams are passed on separately to the two governments.

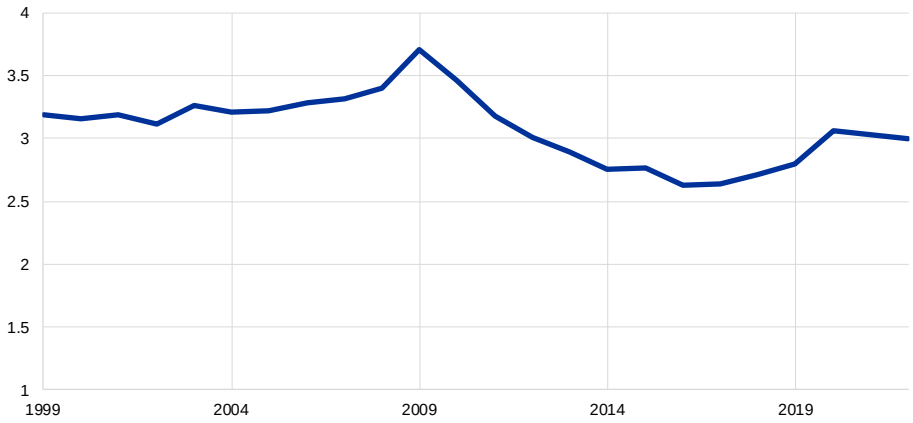
3 Monetary-fiscal policy interactions and the role of public investment

After the global financial crisis, government investment in the euro area as a share of GDP recorded a decline that extended over several years (Chart 9). The disappointing growth performance after the crisis led to a debate on the desirability of increasing public investment, especially given the environment of low interest rates at the time. Even though the public investment ratio has increased somewhat in recent years (up to 2021), it has remained below the pre-crisis level. Despite initiatives to increase public investment in Europe (ECB, 2016), it was not until after the pandemic that an ambitious euro-area wide plan was launched in the form of the NGEU. The centrepiece of this is the Recovery and Resilience Facility (RRF), an instrument that provides grants and loans to support reforms and investment in the EU Member States. This goes well beyond immediate assistance to recover from the crisis and seeks to promote medium-term growth. Member States have to present a coherent package of fiscal measures, in particular public investment and structural reforms, to benefit from loans and grants.

Chart 9

Euro area government investment-to-GDP ratio

(y-axis: percentage of GDP; x-axis: years)



Source: Eurostat.

Initiatives to increase public investment may generate a challenge to monetary policy in a framework where inflation is above target. Initiatives like the NGEU can imply a significant increase in publicly funded investment in the euro area, which can boost demand if not matched by an immediate increase in supply. At the same time, where properly targeted, public investment can also contribute to boosting supply. As long as these efforts support investments that are productive, the macroeconomic effect is likely expansionary, but the effect on inflation is harder to grasp. Depending on the type of public investment being implemented, it may take some time for them to raise productivity and expand the supply side sufficiently to put downward pressure on prices.

In this chapter we explore the impact of government investment on economic activity and inflation, and the ability of monetary policy to counteract an inflationary burst. First, we review the literature on the impact of public investment. Then we analyse these issues using a suite of models, focusing mostly on the short- to medium-run impact of public investment shocks. Finally, we discuss how growth-enhancing fiscal policies (policies aimed at supporting R&D and technology adoption) can potentially help mitigate hysteresis effects, and how they interact with different types of monetary policy framework.

3.1 Literature review on the impact of public investment

The impact of government spending on the business cycle has received prominent attention in the literature over the past decades. [49,50] Both theoretical and empirical studies have tried to identify the effects of public spending on, especially, real GDP. Analysis of shocks to government consumption (or consumption and investment combined) has been extensive, but discussion of public investment has been rarer. This section briefly reviews the relevant literature and focuses on insights regarding the effects of shocks to overall government spending, specifically public investment. While our main focus is on results arising from theoretical models, as these are closely related to the work in this chapter, we also refer to time series evidence to put the model-based findings into perspective.

The output effects of government spending shocks found in DSGE models depend on the characteristics of the economy. Influential studies such as Baxter and King (1993) argue that government spending shocks in standard real business cycle models produce a negative effect on private consumption and investment, but a positive effect on output, given a negative wealth effect that raises labour supply. Cogan et al. (2009) show that government spending multipliers are smaller in New Keynesian frameworks than in neoclassical set-ups, due to greater crowding-out effects. Subsequent research by Galí et al. (2007) indicates that including non-Ricardian consumers and their interaction with sticky prices can account for larger positive effects of government spending on private consumption. Bouakez and Rebei (2007) and Fève et al. (2013, 2017) find larger multipliers and crowding-in effects if total public spending and private consumption present some degree of complementarity. Ercolani and Valle e Azevedo (2014), Drautzburg and Uhlig (2015) and Sims and Wolff (2018) reveal that the value of the output elasticity to public capital in the production function (which determines the marginal productivity of public capital) is key to obtaining high government investment multipliers. All these studies find multipliers below one, both for the short run and the long run.[51]

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[49] This section includes contributions from Michaela Elfsbacka Schmöller (Suomen Pankki), Ivan Kataryniuk (Banco de España), Stephane Moyen (Deutsche Bundesbank) and Edgar Silgado-Gómez (Central Bank of Ireland).

[50] Perotti et al. (2007), Ramey (2011) and Ramey (2019) provide summaries of the literature. Kilponen et al. (2015) employ fifteen dynamic macroeconomic models to investigate the aggregate effects of a temporary fiscal tightening.

[51] Ercolani and Valle e Azevedo (2014) find public investment multipliers above one only when they set the elasticity of output to public capital to a relatively large value (i.e. 0.09 instead of the benchmark value of 0.05 used by Baxter and King, 1993).

The empirical literature points to positive public investment multipliers that are often, but not always, found to be below one. Coenen et al. (2012) look at the impact of different fiscal measures, including public investment, in several structural models of different world economies (three of which are euro area models). They show that output multipliers from government investment and consumption are roughly similar in size. ECB (2016) finds that an increase in public investment generates heterogeneous responses in GDP in the euro area. Pereira and Pereira (2019) employ VAR methods to quantify the impact of different types of infrastructure investment for Portugal and obtain multipliers much larger than one in the short-term. Gechert and Rannenberg (2018) use a meta-regression analysis on a data set of nearly one hundred empirical studies and find that government expenditure multipliers are particularly large for public investment. Ramey (2020) studies the impact of average public investment shocks and collects previous evidence on the effects of infrastructure investment in the US. She finds short-term public investment multipliers generally below one, depending on the modelling structure.

The size of the government spending multiplier also depends on the nature of the shock, and especially whether the shock was anticipated or unexpected.[52] By employing medium-scale DSGE models, Uribe and Schmitt-Grohé (2012) and Born et al. (2013) find that fiscal news shocks play a non-negligible role in business cycle fluctuations, accounting for about 10-15% of the variance in output at business cycle frequencies. For government investment, Leeper et al. (2010) show that implementation delays in public capital and expected fiscal adjustments to deficit-financed spending are crucial to assessing the effects of public investment. Prolonged delays associated with government infrastructure spending can reduce private investment more and raise output less. Mertens and Ravn (2011) find that expected fiscal policy expansions (in the context of tax cuts) reduce the main macroeconomic variables on impact and only raise them after several quarters. Ramey (2011), Forni and Gambetti (2016) and Ricco (2015) have established proxies defining fiscal news as forecast errors (or forecast revisions) on total government spending by using data for the US from the Survey of Professional Forecasters. They conclude that fiscal foresight is crucial if fiscal shocks and their transmission are to be properly identified.

The impact of government spending when the economy is in recession or expansion has received much attention in the literature. Shen and Yang (2018) and Albertini et al. (2021) employ New Keynesian models with involuntary unemployment and generate larger government spending multipliers when the economy features downward nominal wage rigidities in recessionary periods. Jo and Zubairy (2022) exploit the interactions between unemployment and inflation to see whether the size of the multiplier increases during periods of high unemployment. They find that the effect of government spending increases on output is much stronger in low-inflation recessions than high-inflation recessions. Canzoneri et al. (2015) obtain larger multipliers in recessions by adding countercyclical variation in bank intermediation costs to a DSGE model. The empirical studies by Auerbach and

[52] Two other features that influence the size of the multiplier are (a) spending reversals (Cimadomo et al., 2011; Corsetti et al., 2012; Forni and Gambetti, 2016) and (b) how the expenditure shock is financed (Leeper et al., 2010).

Gorodnichenko (2012, 2013) confirm that public spending multipliers are larger during recessions than in booms in the US and in other OECD countries. Furceri and Li (2017) also find evidence of state-contingent government investment multipliers in developing economies. Gechert and Rannenberg (2018), based on a meta-regression analysis of 98 empirical studies with more than 1800 observations on multiplier effects, find that spending multipliers are much higher (by about 0.7-0.9 units) during a downturn. For all spending categories other than government consumption, the multiplier significantly exceeds one during downturns. However, Ramey and Zubairy (2018) argue that the magnifying effects of crises on public spending multipliers are not robust to other empirical strategies and find no statistical differences between boom-and-bust periods in the US.[53]

The stance of monetary policy is also found to be crucial for the size of fiscal multipliers. Woodford (2011), Eggertsson (2011) and Christiano et al. (2011) build theoretical models to argue that the output effects of government spending shocks are more positive when the nominal interest rate is at its zero lower bound (ZLB), implying that multipliers can be much larger than one. Coenen et al. (2013) quantify that public investment multipliers are less than one when monetary policy is not accommodative, but with two years of monetary accommodation the multipliers are 75% higher. Bouakez et al. (2017) also find multipliers below unity in normal times, independently of time-to-build delays in public capital. They obtain multipliers as large as four if the ZLB is accompanied by more prolonged delays, as the latter implies that the deflationary effects of public investment (which work by reducing firms' marginal costs) are pushed further into the future. Hodge et al. (2022) assess the implications of shocks to public investment in both the US and the euro area after the COVID-19 crisis and find that they boost GDP even when monetary policy is constrained at the ELB. Ramey and Zubairy (2018) empirically note that the magnifying impact at the ELB is confirmed under several econometric specifications in the US. Other time-series studies such as Boehm (2020) and Bonam et al. (2020) confirm the theoretical predictions of government investment shocks in the presence of the ELB constraint for a panel of developed countries. While the research mentioned finds that the fiscal multiplier is larger at the ELB, Jørgensen and Ravn (2022) observe that this can change if one introduces variable technology utilisation in a standard DSGE model. Box 6 presents an empirical exercise which analyses fiscal multipliers at and away from the ELB and the results are broadly in line with the existing literature. Liu et al. (2023) analyse the interaction between monetary policy strategy and the impact of fiscal policy and show that the stimulus effects of fiscal policy expansions crucially depend on the extent of history-dependence of average inflation targeting.

Several studies have also investigated the long-term impact of public investment.[54] Bom and Ligthart (2014) use an overlapping-generations model of a small open economy and obtain a long-run output multiplier larger than two, even though in the short run the strong decrease in employment causes output to drop. Mourougane et al. (2016) rely on a range of simulations using three different macro-

[53] Other empirical studies, such as Alloza (2022), support the findings in Ramey and Zubairy (2018).

[54] Scandizzo and Pierleoni (2020) summarise the literature on the effects of public investment shocks in the short and the long run.

structural models and show that government investment shocks raise GDP by more than 1.5% in the long run, whereas the short-run impact is around three times smaller. Hickey et al. (2020) employ the fiscal extension of the EAGLE model and find that the increase of productive public capital in Ireland stimulates output in the medium- and longer term, regardless of how government investment is financed. The model simulations in Abiad et al. (2014) for advanced and developing economies also confirm that public investment shocks are more beneficial in the long term due to the build-up of a higher stock of public capital. Empirical studies related to infrastructure spending, such as Leduc and Wilson (2013), argue that highway spending shocks generate impact multipliers exceeding unity and multipliers as large as seven in the medium term. Ilzetzki et al. (2013) find, for a panel of countries, public investment multipliers larger than one as time passes and smaller than 0.5 upon impact.

The long-run effects of fiscal policy have also been shown empirically to operate through total factor productivity and studied theoretically in models with endogenous growth that account for hysteresis effects. Ilzetzki (2022), for instance, shows causally and empirically that during World War II, increases in government purchases of aircraft in the US led plants in the aircraft industry facing binding capacity constraints to raise total factor productivity (TFP) through a "learning-by-necessity" channel. Antolin-Diaz and Surico (2022) use 125 years of quarterly data for the US and find that government spending shocks help boost private sector productivity and innovation, which results in a long-run fiscal multiplier above one.[55] Elfsbacka Schmöller and Spitzer (2022) show, in a New Keynesian model with an endogenous trend growth, that adverse shocks can lead to long-lasting hysteresis effects and permanent output losses due to a decline in R&D investment and technology adoption that lowers TFP growth.[56]

3.2 The effects of public investment: a business cycle perspective

This section focuses on the short to medium-run challenges for monetary-fiscal policy interactions when there is an increase in public investment.[57] Harmonised exercises are performed across different structural- and semi-structural models to understand the macroeconomic impact of public investment. The set of euro area models used includes some multi-country models, namely the EAGLE

55 With regards monetary policy, Jordà et al. (2022) show empirically the long-run effects of monetary policy operating through TFP by means of local projections. Moran and Queralto (2018) provide further time series evidence on the long-term effects of monetary policy. Garga and Singh (2021) study optimal monetary policy in a New Keynesian model with endogenous trend growth.

56 Aikman et al. (2022) and Furlanetto et al. (2021) provide empirical evidence on hysteresis effects. Elfsbacka Schmöller, Goldfayn-Frank and Schmidt (2023) provide empirical evidence for hysteresis effects on TFP at the firm level. Fornaro and Wolf (2020) study the mechanisms of long-run scars following supply-side disruptions.

57 This section includes contributions from Pierre Aldama (Banque de France), Ginters Bušs (Latvijas Banka), Sandra Gomes (Banco de Portugal), Pascal Jacquinot (ECB), Alessandro Notarpietro (Banca d'Italia), Dimitris Papageorgiou (Bank of Greece), Ansgar Rannenberg (Nationale Bank van België/Banque Nationale de Belgique), Edgar Silgado-Gómez (Central Bank of Ireland), Ifigeneia Skotida (Bank of Greece) and Martin Železník (Národná banka Slovenska).

model fiscal extension with different calibrations (EAGLE6, EAGLE-SK and EAGLE-IREL) and a medium-scale DSGE model of the euro area (called "BdI model" in the charts), a closed-economy model, the POSA (Preference Over Safe Assets) model, and two semi-structural models: the EA-BDF model and the ECB-BASE model. In addition, two small open economy DSGE models are considered in some simulations: the BoGGEM and Latvia's fiscal model.[58] To facilitate comparison of the results across these models, the same monetary policy and fiscal policy rules are considered. The following shocks are simulated: a euro area transitory government investment shock, a euro area transitory government investment shock with forward guidance, a euro area permanent government investment shock and a domestic transitory government investment shock.

3.2.1 Euro area-wide shocks

The goal of this section is to show the effect of public investment across a variety of models. Even though most of the models considered have a New Keynesian core, there are many dimensions along which they differ. To enhance comparability, we harmonise the simulation exercise as follows. First, we focus on euro area-wide shocks, which helps to narrow the degree of heterogeneity among models. Second, we harmonise the fiscal and monetary policy rules across models, so the differences obtained are not due to structural differences in the policy reaction.[59] We start by simulating an exogenous increase in public investment of 1% of pre-shock GDP over eight quarters, during which the fiscal rule stabilising public debt is deactivated. After eight quarters the shock disappears, following an AR(1) process with a decay parameter equal to 0.5, and the fiscal rule is reactivated. The results are summarised in Chart 10.

A euro area-wide transitory public investment shock leads to an expansion of economic activity together with a moderate and short-lived increase in inflation, which generates a tightening of monetary policy that partially counteracts these effects. Euro area GDP rises in the short run in all models, although there are some quantitative differences. These are most pronounced for the behaviour of private consumption and private investment, which can partly be explained by modelling choices. In most cases, the shock leads to an increase in private consumption in the short run, which is less pronounced in the case of the EAGLE-IREL model. Most models include a share of non-Ricardian households; the POSA model is an exception. The positive effect on consumption during the first two years or so comes mainly from the wealth effect of higher government debt on consumption, and to a lesser effect from the higher productivity due to higher public capital and the associated looser monetary policy. This balance reverses later as government debt returns to the steady state. For private investment, most models predict a positive response following the public investment shock, even though there

[58] For details of the models see the appendix.

[59] In the fiscal policy rule, lump-sum taxes are used to stabilise the public debt-to-GDP ratio, where the parameter associated with the debt ratio is set to 0.1 (we abstract from a fiscal response to the output gap). In the monetary policy rule, the policy rate reacts to year-on-year inflation and quarterly output growth according to $R_t = \rho R_{t-1} + (1-\rho)[\bar{R} + \theta_\pi(\pi_t - \bar{\pi})] + \theta_y Ygrowth_t$, where $\rho = 0.87, \theta_\pi = 1.7, \theta_y = 0.1$ and variables with an upper bar represent steady-state values.

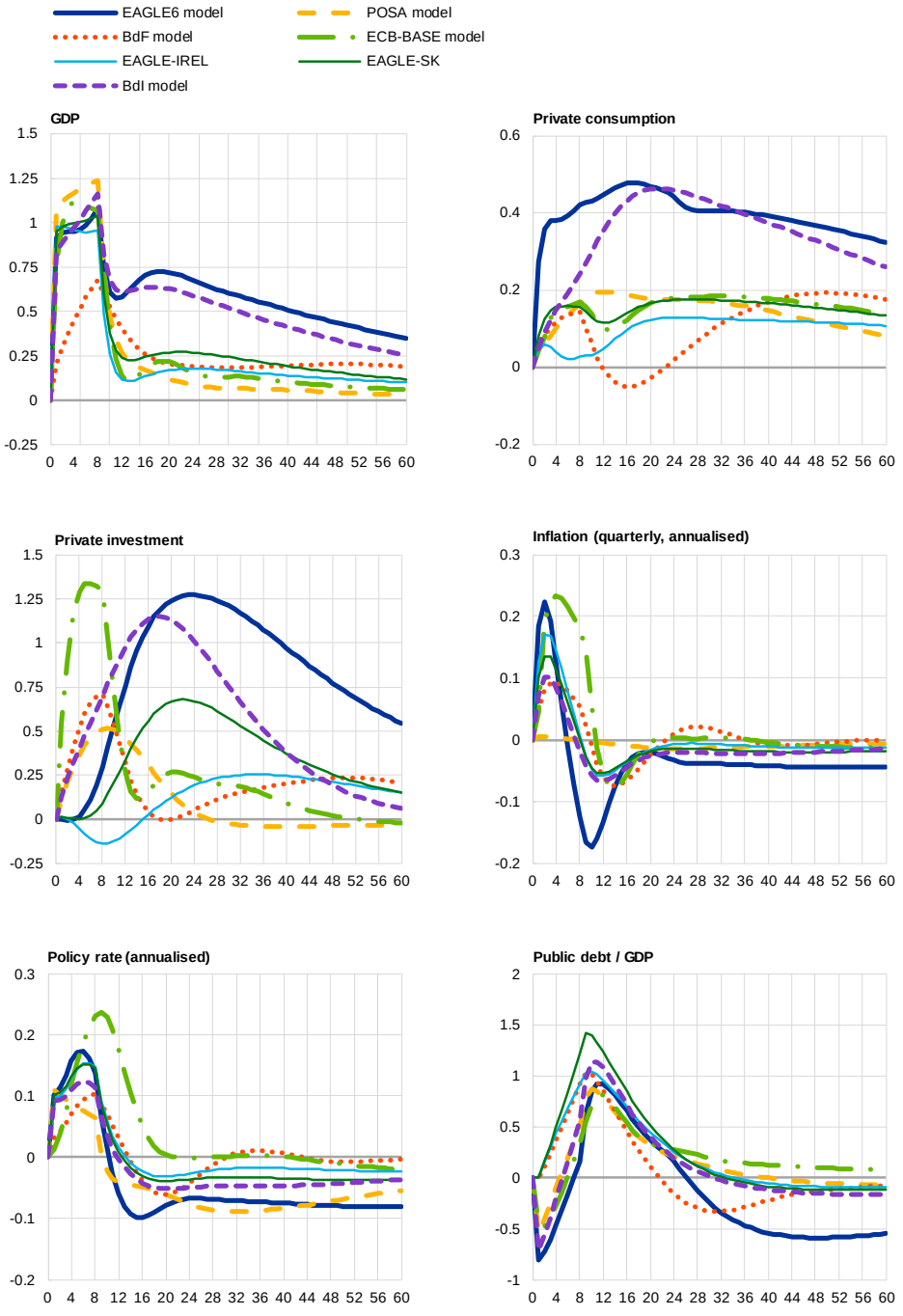
are some differences in the strength of the short-run response across models, with a small decline in the EAGLE-IREL model. Since most models assume public capital directly enters firms' production function, the accumulation of public capital stimulates aggregate supply. In the EA-BDF model public capital does not enter the production function, which hence does not allow for supply-side effects of public investment shocks. To account for these effects, exogenous TFP shocks calibrated to the size of the shock on capital and with an elasticity of output to public capital in line with those found in the empirical literature were added (see Bom and Ligthart, 2014).

The inflationary impact of the public investment shock is crucial to understanding the corresponding monetary policy response. In general, as evidenced by all models, the public investment shock generates temporarily higher inflation in the short run. As a result of the rise in GDP and inflation, monetary policy reacts by increasing the policy interest rate to bring inflation to the central bank's target over the medium run. The inflation response in ECB-BASE is more persistent than in other models, which translates into a larger and more persistent policy rate increase.

Chart 10

Euro area impulse response functions to a transitory public investment shock

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



Source: Authors' calculations.
Notes: GDP, private consumption and private investment are expressed in percentage deviations from steady state; inflation and the policy rate are annualised and reported in percentage point deviations from steady state. Public debt as a ratio to annualised GDP is reported in percentage point deviation from steady state.

The public debt-to-GDP ratio generally rises following the public investment shock. Some models show an initial drop in the public debt ratio, due to a denominator effect (an increase in GDP that lowers the debt-to-GDP ratio, even

though public debt rises in absolute terms). Even in these few cases, however, public debt rises temporarily following the initial drop.

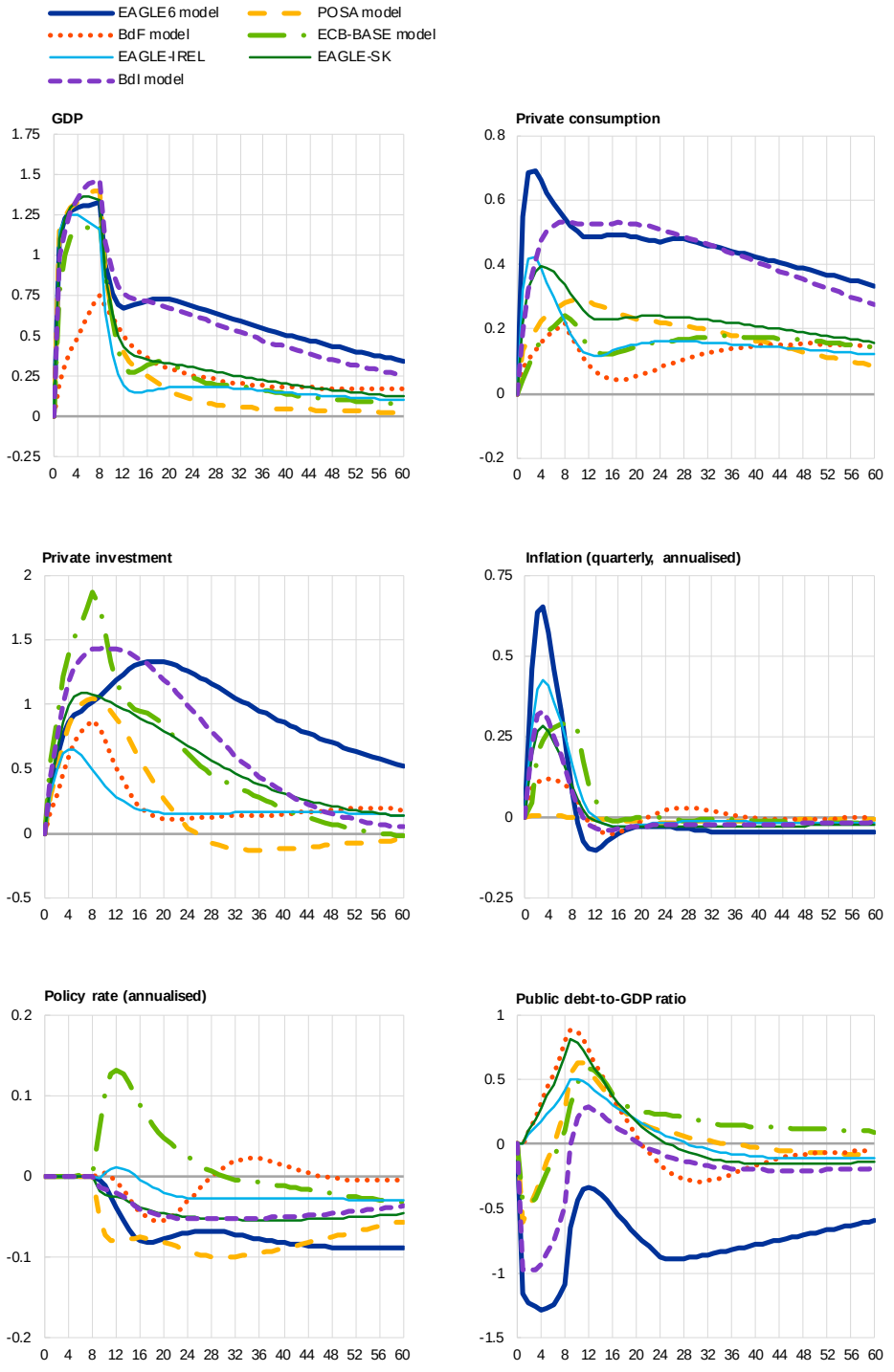
If monetary policy does not react immediately to the expansionary and inflationary impact of the public investment shock, the macroeconomic impact is amplified, depending on the modelling choices. Given that the increase in public investment generates an expansion of GDP and an increase in inflation, the monetary authority reacts by increasing the policy interest rate. We should recall that we harmonise the monetary policy rule – that is, the functional form of the rule and the coefficients that govern the mechanical response of the policy rate to a given change in inflation and output growth. However, macroeconomic outcomes can be different across models, so the endogenous response of monetary policy can also be different. To abstract from the impact of the monetary policy actions, we run a similar simulation across models where we consider the same increase in public investment but assume that policy rates are unchanged for eight quarters (Chart 11). The fact that interest rates are kept unchanged over the period when government investment increases leads, as expected, to a larger impact of the shock compared to the case of an immediate monetary policy response. GDP, consumption and investment show larger increases. The inflation response is also magnified. As the inflation response is more persistent in ECB-BASE than in other models, lasting beyond the period during which the rate is unresponsive, in this model there is an increase in the policy rate after the eighth quarter, unlike in other models. The differences between the first scenario and the scenario with temporarily unchanged policy rates are smaller in the case of the POSA and EA-BDF models. In the former, the effect of monetary accommodation on the fiscal multiplier and inflation is attenuated by the POSA feature itself (see Rannenberg, 2021), as well as by the relatively high estimate of the degree of nominal rigidity and fixed costs in production, which render the aggregate supply curve very flat.[60] In the EA-BDF model, accommodative monetary policy only modestly amplifies the expansionary effects of government spending, compared with the results obtained from the other models. This may be explained by the lower sensitivity to interest rates of household consumption in semi-structural models, which dampens the effects of an increase in inflation expectations generated by the government spending stimulus on the real interest rate and consumption when monetary policy does not react immediately.

[60] The relative high estimates of the degree of nominal rigidity and fixed costs are partially a feature of the euro area macro data and partially a result of the inclusion of measures of interest rate expectations in the dataset (see Rannenberg, 2019, and Rannenberg, 2021).

Chart 11

Euro area impulse response functions to a transitory public investment shock with unchanged interest rates for two years

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



Source: Authors' calculations.
Notes: GDP, private consumption and private investment expressed in percentage deviations from steady state; inflation and the policy rate are annualised and reported in percentage point deviations from steady state. Public debt as a ratio to annualised GDP is reported in percentage point deviation from steady state.

Differences across models in the responses following the public investment shock are larger when the shock is permanent rather than transitory. Chart 12 shows the results of a permanent increase in euro area public investment amounting to 1% of pre-shock GDP. We consider the same harmonised fiscal and monetary policy rules as before. Despite larger differences across models than in the case of a transitory shock, in all models the permanent increase in public investment generates an expansion of GDP and an increase in inflation. For all models, the public investment long-run multiplier is above unity. The rise in inflation can, according to several models, be quite persistent. Differences in the case of the EA-BDF model seem to result from the relatively small estimated short-run slope of the Phillips curve.[61] Private consumption and private investment show considerable differences across models. In most cases, private consumption falls in the short term and then increases to a new long-run value, reflecting intertemporal substitution. In the POSA model the stronger increase in private consumption and investment, and thus output, is partly the result of the model features implying a wealth effect of government debt on consumption. This combines with the high estimated nominal rigidity, limiting the rise in the real interest rate. Investment then rises because of the persistent increase in output. The rise in the policy rate is larger and longer compared to the case of a temporary increase in public investment, reflecting a stronger effect of the permanent shock both on inflation and on economic activity.[62]

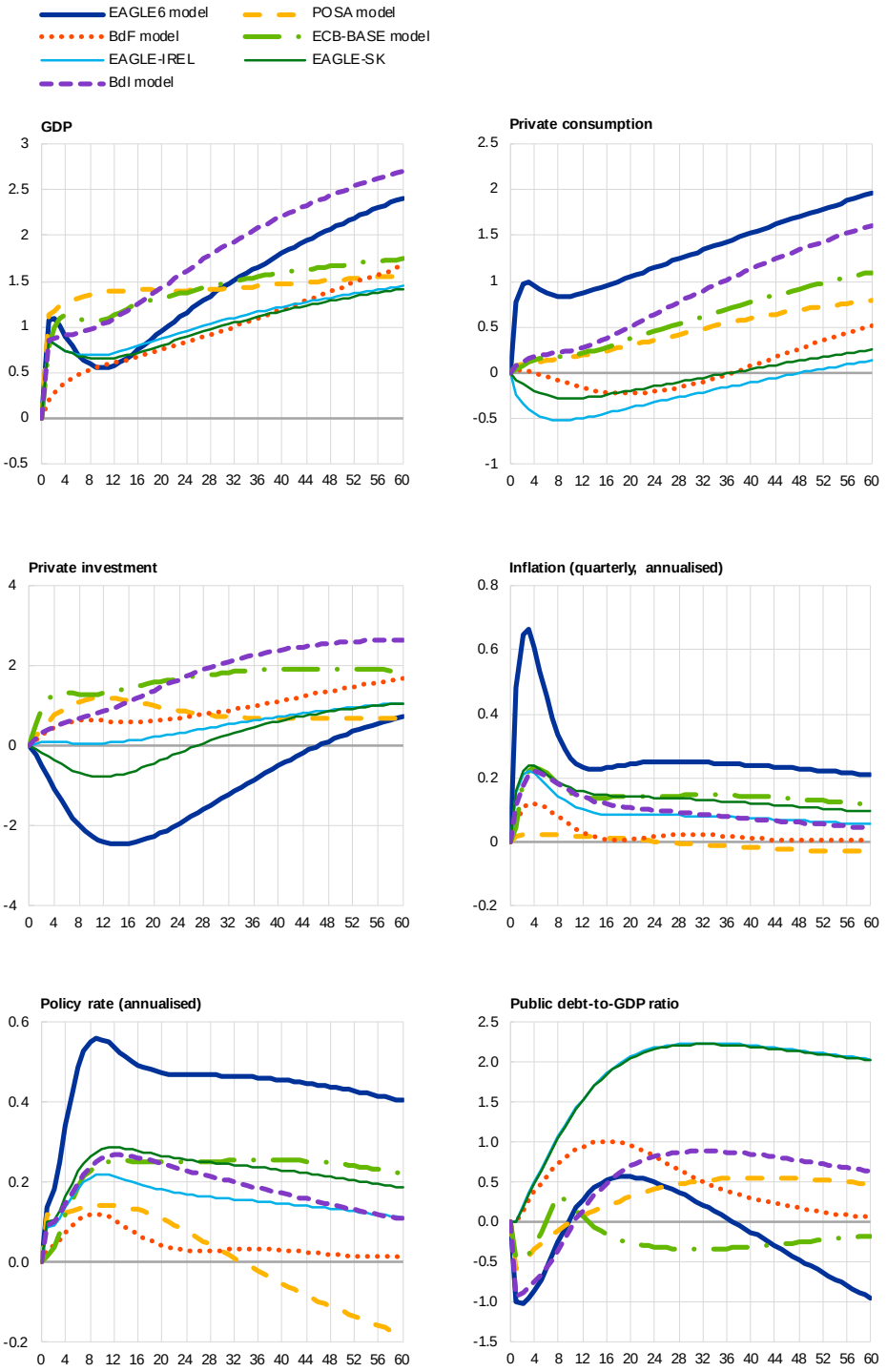
[61] In EA-BDF, the Phillips curve long-run slope of the rest-of-euro area block is estimated at 0.27 (Aldama et al. 2022, p.10) while the long-run slope for France is higher (0.45, see Lemoine et al., 2019).

[62] On the response of the public debt-to-GDP ratio in the BdI model, see the comments in the previous section.

Chart 12

Euro area impulse response functions to a permanent public investment shock

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



Source: Authors' calculations.
Notes: GDP, private consumption and private investment expressed in percentage deviations from steady state; inflation and the policy rate are annualised and reported in percentage point deviations from steady state. Public debt as a ratio to annualised GDP is reported in percentage point deviation from steady state.

3.2.2 Country-specific shocks

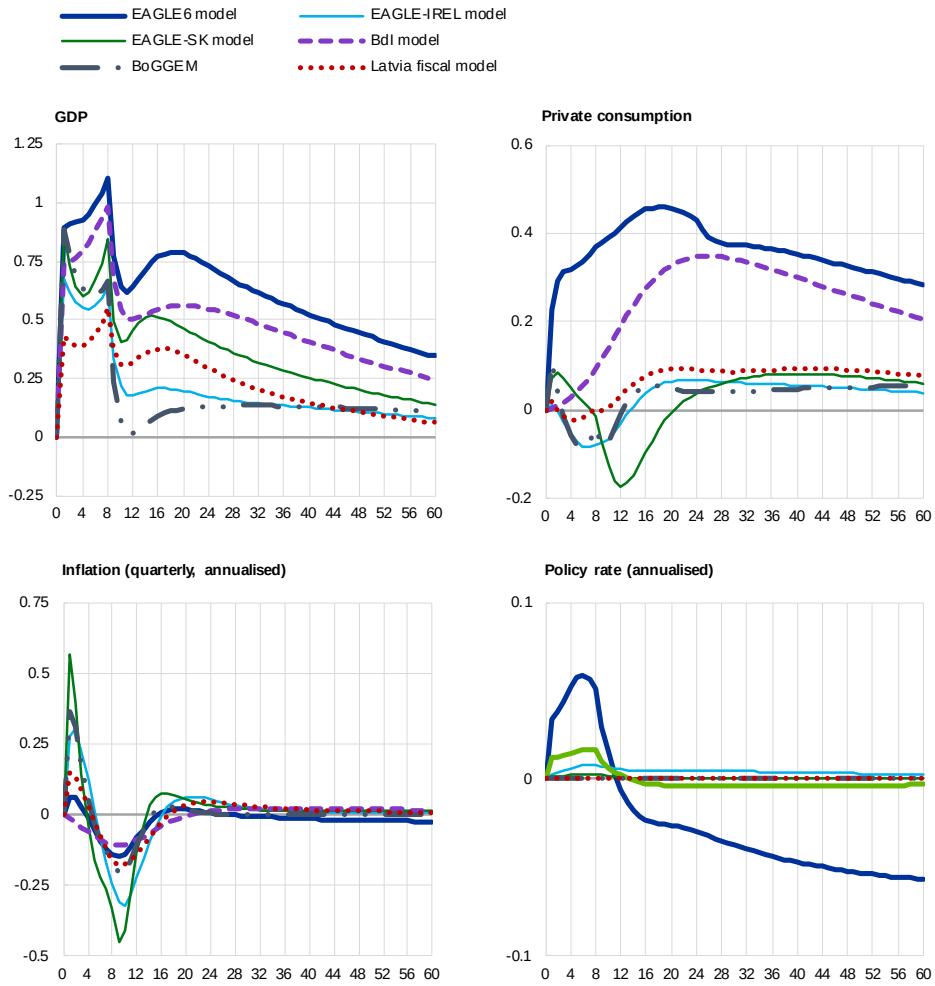
If the public investment shock occurs only in a part of the euro area, the monetary policy response depends crucially on the size of the region. In the euro area, changes in public investment and fiscal policy more generally are decided and implemented at the national level. Even though an initiative such as the NGEU generates a common effort that includes public investment plans in the euro area, implementation is still heterogeneous at the national level. In this section, we show the results of a temporary public investment shock with the same characteristics as the one simulated in the previous section. However, we now assume that the shock occurs only in a domestic economy which is part of the euro area. The economy in question differs across models and is as follows: Germany in the EAGLE6 model (around 30% of the euro area), France in the BDF model (20% of the euro area), a relatively small euro area economy in the BdI model (12% of the euro area), Ireland in EAGLE-IREL (1.5% of the euro area) and Slovakia in EAGLE-SK (0.6% of the euro area). The BoGGEM (a model of Greece) and Latvia's fiscal model are small-open economy models. The POSA model is not used in this section as it is a closed-economy model of the euro area.

Responses to the country-specific public investment shocks differ significantly across models, reflecting differences in economies' size and model structure (Chart 13). The shock implies fairly similar responses in GDP across all models in the short run. In general, the shock is inflationary initially, given that domestic demand increases. In most cases the increase in inflation does not lead to a monetary policy response, due to the small size of most of the economies considered. This is less so in the case of the EAGLE6 model, where the domestic economy is equivalent to around 30% of the euro area.

Chart 13

Domestic impulse response functions to a temporary domestic public investment shock

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



Source: Authors' calculations.
Notes: GDP expressed in percentage deviation from steady state; inflation and the policy rate are annualised and reported in percentage point deviations from steady state.

Country-specific public investment shocks are generally inflationary in the short run, causing a monetary policy tightening (especially if the country is relatively large), but reduce inflation in the medium run. In all cases, despite the differences in the characteristics of the domestic economy and model features more generally, the short-term public investment multiplier lies between 0.5 and 1. The increase in public investment will only prompt a response in monetary policy if it occurs in a sufficiently large part of the euro area. We have simulated a stylised public investment shock both in the euro area and specific economies but have not looked at the actual plans included in the NGEU initiative. Box 7 looks at the implications of this programme for monetary/fiscal policy interactions.

Box 6 The effects of public investment at the effective lower bound

Prepared by Edgar Silgado-Gómez (Central Bank of Ireland)

This box empirically investigates monetary-fiscal policy interactions by estimating the impact of government investment shocks on the macroeconomy in times when conventional monetary policy is constrained by the ELB. To this end, we employ local projection (LP) techniques for a panel of countries in the euro area (Germany, France, Italy, and Spain).

The empirical strategy relies on the following panel LP regression:

$$y_{j,t+h} - y_{j,t-1} = \alpha_{j,h}(s_{j,t+h} - s_{j,t-1}) + \beta_{j,h}(L)x_{j,t-1} + \gamma_{j,h} + \delta_{t,h} + \varepsilon_{j,t+h}$$

where $y_{j,t}$ denotes real GDP, $s_{j,t}$ real public investment, $\beta_{j,h}(L)$ a polynomial in the lag operator, and $x_{j,t}$ a set of controls. The latter includes two lags of the changes in real public consumption, public investment, GDP, the GDP deflator, the ratio of public debt to GDP[63] and tax revenues net of total transfers. Several of these control variables are employed in seminal contributions to the related literature (see e.g. Blanchard and Perotti, 2002; Ramey, 2011; Auerbach and Gorodnichenko, 2012). Variables are expressed in logs, except for the debt-to-GDP ratio, which enters in levels. We include time and country fixed-effects in our baseline estimation.

In order to identify a public investment shock, we rely on a similar assumption imposed on the identification of total government spending shocks: it takes longer than a quarter for the government to respond to new information in the economic environment (Blanchard and Perotti, 2002).[64] Notice also that we include government consumption in our vector of controls to purify the impact of our shock of interest.[65] We compute cumulative impulse response functions (IRFs) for a time horizon of ten quarters. Confidence bands are based on Newey-West robust standard errors to account for the potential correlation of the error term across countries.

There is evidence in the literature that the effects of public investment shocks hinge on the ELB being binding or not (Bouakez et al., 2017). We alter the econometric specification to encompass the possibility of these asymmetries at and away from the ELB as follows:

$$y_{j,t+h} - y_{j,t-1} = I_{j,t-1}\left[\alpha^{A}_{j,h}(s_{j,t+h} - s_{j,t-1}) + \beta^{A}_{j,h}(L)x_{j,t-1}\right] +$$

$$+(1 - I_{j,t-1})\left[\alpha^{B}_{j,h}(s_{j,t+h} - s_{j,t-1}) + \beta^{B}_{j,h}(L)x_{j,t-1}\right] + \gamma_{j,h} + \delta_{t,h} + \varepsilon_{j,t+h}$$

where $I_{j,t}$ is a dummy variable representing the case when the ELB binds in country j when the shock hits.[66] Following Bonam et al. (2020), we define a binding ELB as a nominal interest rate below 1% for four consecutive quarters.[67]

63 See Cimadomo et al. (2011) for the importance of adding government debt as a control variable in identifying government spending shocks. Data on government debt is obtained from Eurostat.

64 Recall that the previous regression is equivalent to the VAR identification of Blanchard and Perotti (2002), since we include in the set of controls lagged measures of real GDP and government spending, among others.

65 We also allow public consumption to enter directly on impact. The baseline results are unchanged.

66 The dummy variable $I_{j,t}$ will enter in general at *t-1* to avoid contemporaneous feedback from policy actions with respect to the state of the economy (Auerbach and Gorodnichenko, 2012, 2013; and Ramey and Zubairy, 2018).

67 In this exercise, the dummy variable $I_{j,t}$ enters at time *t,* similar to Bonam et al. (2022). Analogous results are obtained when a lag of the dummy indicator is employed.

The model is estimated using a quarterly dataset for Germany, Spain, France and Italy. The data is assembled by Alloza et al. (2019), who compile a detailed fiscal block for these economies under consistent and comparable criteria. The data spans the period from the first quarter of 2000 to the fourth quarter of 2018, for which a balanced quarterly dataset for public debt according to the excessive deficit procedure is available.[68]

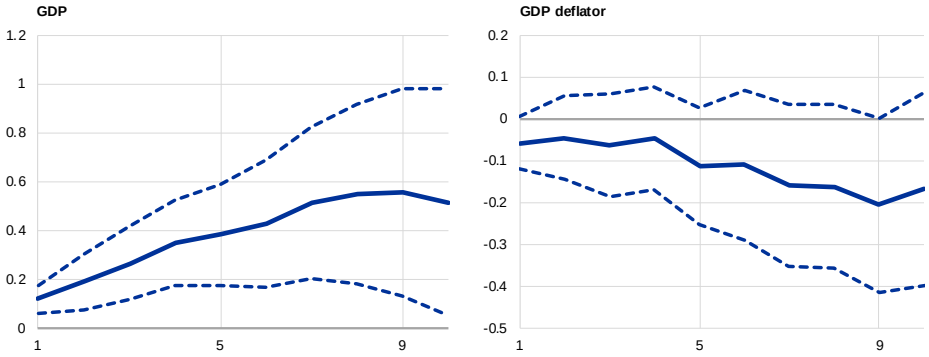
Chart A shows the linear unconditional IRFs to a 10% increase in public investment on GDP.[69] Output significantly rises on impact by 0.12% and reaches a value of around 0.55% after two years. The response in prices is ambiguous, although the mass of its distribution is inclined towards the negative plane.

In terms of fiscal multipliers, if we scale the cumulative multiplier by the sample average ratio between public investment and GDP (around 3% of GDP) we obtain an impact multiplier of 0.40 and a two-year fiscal multiplier of 1.80.[70] These values are consistent with previous literature. For a panel of advanced economies, Abiad et al. (2016) also find a similar fiscal short-run multiplier of around 0.5. Ilzetzki et al. (2013), Kraay (2014) and Furceri and Li (2017) obtain fiscal multipliers between 0 and 0.6 for developing economies. At longer horizons, the results are in line with Leduc and Wilson (2013) and Ilzetzki et al. (2013), who find public investment multipliers larger than one. Bom and Ligthart (2014) obtain long-run multipliers larger than two by using an overlapping-generations model of a small open economy.

Chart A

Linear IRFs of GDP (left) and GDP deflator to a 10% increase in public investment.

(y-axes: percentage deviations from steady state; x-axes: quarters)



Source: Author's calculations.
Note: Chart shows the median and 90% confidence bands (based on Newey-West robust standard errors).

68 We have also expanded the dataset to consider annual data on public debt back to 1991. These data are available in annual terms; we then convert annual figures into quarterly ones by applying cubic-spline interpolation methods. This allows us to make use of more recessionary episodes and check if the baseline results are robust to different time spans. We have re-estimated all the regressions and our findings during ELB regimes are robust to changes in the starting date.

69 An increase of 1 percentage point in GDP represents a sample average increase of 30% in government investment levels, rising from approximately 3% of GDP to 4%. This figure is somewhat larger for all the countries in our analysis. Thus, we have decided to provide a smaller figure of 10%.

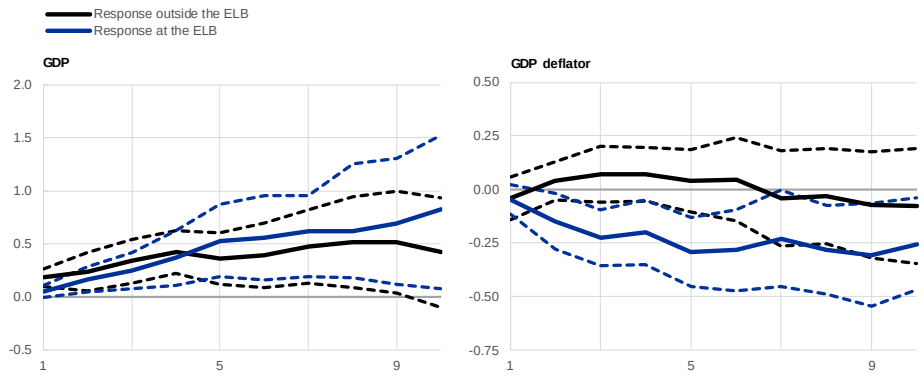
70 The sample average ratio between public investment and GDP is stable over time. This potentially avoids the critique by Ramey and Zubairy (2018) when transforming elasticities into multipliers.

Focusing on the interaction between fiscal and monetary policies, we ask how transmission of a government investment shock changes when monetary policy is constrained by the ELB. We test this by interacting the government investment shock with a dummy variable that takes a value of one when the ELB is nearly binding and zero otherwise.

Chart B does not find any notable differences in the short-run effects of public investment shocks on GDP between states where the ELB is binding and when it is not.[71] However, it does seem that the positive effect on GDP is more pronounced at the ELB at longer horizons. The lack of large differences among these two regimes is consistent with the analysis of Jørgensen and Ravn (2022), who observe that the effects at the ELB are conditional to the response of inflation. They argue (as in Woodford, 2011 and Eggertsson, 2011) that the fiscal multiplier is larger at the ELB because the monetary authority does not increase the nominal interest rate in the aftermath of a rise in inflation, but they do not find empirical evidence of an inflationary effect. On the contrary, they find that prices drop or barely respond to a government spending shock in the US. Our set of countries seems to suggest a similar conclusion for the case of public investment (see right-hand panel in Chart B). Bonam et al. (2020) show that shocks to government investment tend to lower inflation through a reduction in marginal costs, which would then lead to an increase in the real interest rate (due to the ELB) that in turn offsets the expansionary fiscal effects. They find that this is the case for equipment-related public investment, but not for construction-related, which typically has a longer time-to-build constraint.

Chart B Non-linear IRFs of GDP and GDP deflator to a 10% increase in public investment.

(y-axes: percentage deviations from steady state; x-axes: quarters)



Source: Author's calculations.
Notes: The blue lines show the response at the ELB, while the black lines show the responses outside the ELB. Each entry shows the median and 90% confidence bands (based on Newey-West robust standard errors).

Box 7 NGEU and the implications for monetary/fiscal policy interactions

Prepared by Kostas Mavromatis (De Nederlandsche Bank)

On 21 July 2020 the European Council agreed on the European Union's recovery instrument, the Next Generation EU (NGEU) package, as a means to support the recovery of Member States hit hard by the pandemic. In particular, the European Union agreed on a recovery fund of €750 billion split into grants and loans to local governments for the period 2021 to 2026, financed by issuing

[71] We get similar findings under different definitions of the ELB constraint, i.e. we also assess the case when the nominal interest rate is below 1% during the current and/or the previous quarter.

common debt. This box aims to explore the extent to which NGEU funds can mitigate a recession in the euro area when the latter is subject to a uniform adverse supply shock. To that end, the implications for the monetary and fiscal policy interactions are also analysed. The EAGLE model is used, extended by a supranational fiscal authority operating in the euro area, and the focus is restricted to grants to Member States rather than loans. The grants considered are direct transfers to the non-tradables sector, transfers to local governments to finance part of government expenditure, and subsidies for private investment.[72]

Common EU bonds are introduced in EAGLE by allowing the supranational fiscal authority to issue long-term bonds, in the spirit of Woodford (2001), which are assumed to be traded only within the euro area. The maturity of those bonds is calibrated to 25 years – that is, before the publicly announced deadline of December 2058. There are three sources of revenues of the supranational fiscal authority: an EU VAT imposed on households in the euro area; contributions from each Member State weighed by size in the form of EU lump-sum taxes; and an EU financial transaction tax on households that have access to financial markets.[73] Specifically, households that have access to financial markets pay a tax proportional to their new bond holdings in every period. The tax is imposed on all their new asset holdings, including those of long-term bonds issued by the supranational authority.

The scenario considered assumes that the euro area is subject to an adverse supply shock. Fiscal policy is conducted by each member state independently, with local lump-sum taxes being the only debt-stabilising instrument. Monetary policy is assumed to be conducted through a Taylor rule on the short-term rate. The long-term rate on bonds issued by the supranational authority differs from the short-term rate due to a wedge governed by a debt-elastic interest rate premium, as in Justiniano and Preston (2010).

In Chart A below, the scenario of direct transfers to the non-tradables sector is considered. This type of transfer aims at boosting output in the non-tradable sector and labour demand. The three types of sources of revenue of the supranational authority are considered separately. Direct transfers to the non-tradables sector stimulate output in that sector and, given its important share, aggregate output, effectively offsetting downward pressures to output. Specifically, the direct effect of the transfers is an increase in non-tradables output, while the indirect effect stems from higher labour demand, and thus higher wages that in turn boost private consumption. Given wage stickiness, the indirect effect is slightly attenuated however. Looking at the differences depending on the sources of revenue of the supranational fiscal authority, financing via EU VAT leads to a higher inflation peak, triggering a higher peak in the policy rate compared to the other two sources of financing. The larger expansion in this case is due to the lower real rate in the initial quarters after the shock. The present value of wealth increases more now, which allows private consumption to stay higher than in the other scenarios. The policy rate stays persistently higher compared to the

[72] Services sectors were hit the most by the pandemic, which is why transfers to the non-tradable sector are considered. Subsidies for private investment are considered since encouraging private investment is one of the NGEU's objectives. Finally, transfers to finance local government expenditure serve the purpose of approximating EU financial support for reforms.

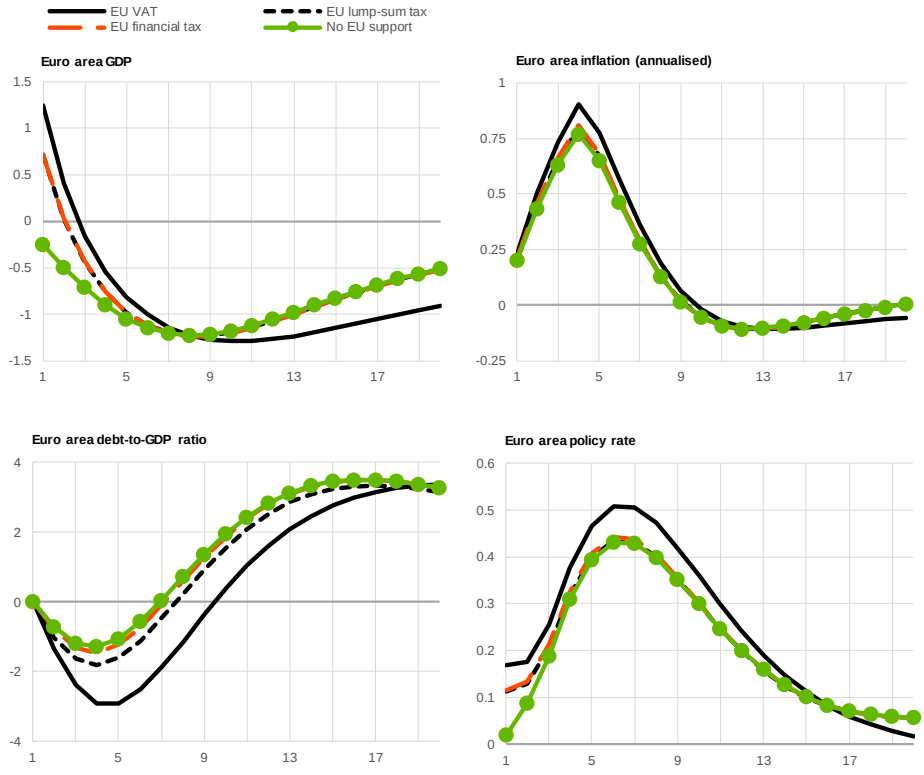
[73] Originally, the EU sources originated from traditional own resources, VAT-based own resources, and GNI-based contributions. Since the adoption of NGEU, additional sources have included the Carbon Border Adjustment Mechanism, a digital tax on large digital corporations, revision of the ETS scheme and a financial transaction tax. The latter type of source has been introduced to guarantee a fair contribution by the financial sector to national tax revenues. Given that a financial sector is absent in the model, the financial tax is assumed to be imposed on wealthy households' new bond holdings. The latter refer only to bonds issued within the euro area, either by local governments or the supranational fiscal authority.

rest of the cases considered because of the inflationary nature of VAT. These eventualities explain why, in the medium run, the recovery is slower compared to the no-EU support scenario. The debt-to-GDP ratio of the euro area declines more under EU VAT financing, owing to the larger expansion in the short run, as well as the lower real debt servicing costs initially and the larger fall in GDP in the medium term. This translates into lower lump-sum taxes imposed by the domestic governments alleviating the negative effects of the supply shock on the consumption of non-Ricardian households. Notice though, that when the supranational authority finances its debt with EU lump-sum taxes, inflation peaks at a slightly lower level, leading to a lower peak in the policy rate.

Chart A

Transfers to the non-tradable goods sector – impulse response functions under different forms of EU debt financing

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



Source: Author's calculations.
Notes: The three types of financing considered are: VAT (solid black line), lump-sum taxes (dashed black line) and financial taxes (red long dashed line). The green-circled lines depict the case of no NGEU support. The euro area debt-to-GDP ratio is the aggregation of domestic government debt-to-GDP ratios.

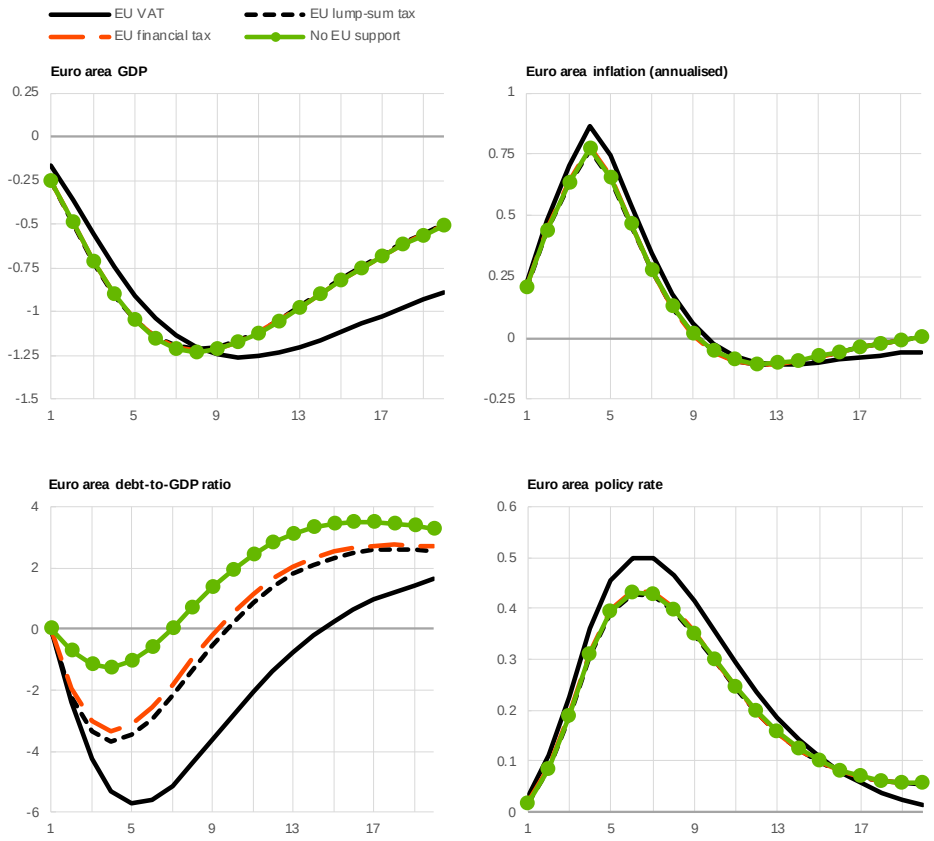
Chart B considers the scenario of transfers to national governments. Direct transfers to local governments alleviate their debt burden, leading to lower local lump-sum taxes and higher lump-sum transfers to households. Looking again at each EU fiscal instrument separately, the differences in the effects on output in the euro area are now marginal until quarter ten, whereas subsequently the contraction is deeper and the recovery substantially lower under EU VAT. Similar to the previous case, not least given its inflationary nature, inflation peaks at a marginally higher level under EU VAT while the terminal rate lies above its level under the other two alternative EU fiscal instruments. Turning to the debt-to-GDP ratio, a similar pattern is observed as before, with a trough being lower under EU VAT, while long-term stabilisation seems to be better achieved under EU lump-sum taxes. In this scenario, the short-run effects on output under the different EU financing instrument is only

marginal, since households use the additional resources from local transfers or lower local taxes to cover taxes related to EU financing. This also explains why the expansionary effects on output are now substantially weaker in the short run.

Chart B

Transfers to national governments – Impulse response functions under different forms of EU debt financing

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



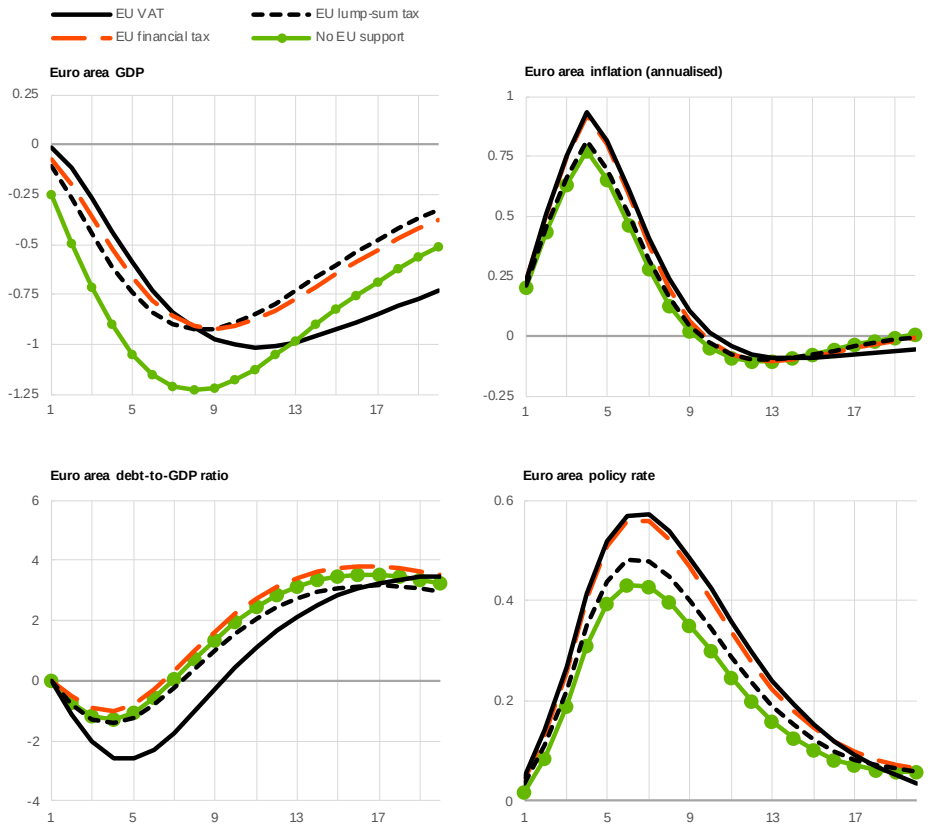
Source: Author's calculations.
Notes: The three types of financing considered are: VAT (solid black line), lump-sum taxes (dashed black line) and financial taxes (red long dashed line). The green-circled lines depict the case of no NGEU support. The euro area debt-to-GDP ratio is the aggregation of domestic government debt-to-GDP ratios.

Chart C considers the scenario of subsidies for private investment. This scheme is introduced by assuming that the EU subsidises income from capital ownership, which in turn boosts private investment. By adopting this scheme, the recession is now mitigated throughout the horizon considered, whether subsidies are financed through lump-sum or financial taxes. When subsidies are financed by lump-sum taxes, the recovery is again slower, but, importantly, the trough of the recession is now lower. This type of subsidy seems to substantially mitigate the adverse effects of higher real interest rates on private investment. Given investment adjustment costs, the high degrees of persistence in investment explain why the recession is now persistently milder compared to the case of no EU support. However, this happens at the expense of a higher inflation peak for the case of financing through a financial tax. As a result, stronger monetary tightening is deemed necessary in this case. When financing is via lump-sum taxes instead, the recession is equally dampened, but without any additional inflationary consequences compared to the scenario of no EU support.

Chart C

Subsidies for private investment – impulse response functions under different forms of EU debt financing

(y-axes: percentage/percentage point deviations from steady state; x-axes: quarters)



Source: Author's calculations.
Notes: The three types of financing considered are: VAT (solid black line), lump-sum taxes (dashed black line) and financial taxes (red long dashed line). The green-circled lines depict the case of no NGEU support. The euro area debt-to-GDP ratio is the aggregation of domestic government debt-to-GDP ratios.

The purpose of the analysis conducted in this box was to explore to what extent NGEU funds help mitigate the contractionary effects of an adverse euro area-wide supply shock. Three scenarios of NGEU schemes were considered: transfers to the non-tradable sectors; transfers to national governments; and subsidies for private investment. Of those three, the analysis shows that the latter is the most successful in considerably mitigating the recessionary effect of supply shocks, though at the expense of potentially higher inflation and stronger monetary tightening. Transfers to the non-tradable sector may generate some benefits in terms of output, but these are short-lived since the economy enters on a contraction path similar to that obtained in the absence of EU funds. In the case of transfers to national governments, the benefits in terms of output losses are either mild or completely absent. In all the scenarios above, EU VAT leads to higher inflation making a stronger monetary contraction necessary, given its inflationary nature. This explains the deeper contractions in the medium run relative to the other two alternative ways of financing. On the fiscal policy side, when the supranational authority finances its debt via EU VAT, more fiscal space is generated for local governments in the short- to medium-run, allowing them to lower their taxes more. In the medium run though, local governments might have to switch to a slightly bolder fiscal tightening, as debt seems to start overshooting at a faster pace. Given their non-distortionary

nature, EU lump-sum taxes are associated with weaker monetary contractions and a milder local fiscal tightening in the medium run.

3.3 The effects of public investment: a long-run perspective

This section looks at the long-run effects of fiscal policy and discusses the implications for monetary policy.[74] The euro area faces multiple challenges over the medium- to long run, such as climate change, digitisation, geopolitical risks and ageing populations. Moreover, persistent and widening macroeconomic imbalances across euro area countries leave the currency union more vulnerable to adverse shocks and debt sustainability risks and could impair the transmission mechanism of monetary policy. Facing these challenges and making the euro area more resilient calls for higher levels of public investment. The establishment of the NGEU in 2020 was in part meant to support Member States in reaching these and other objectives. In contrast to the previous section, which focused on the effects of public investment in the short run, here we take a long-run perspective by considering the possibility that public expenditure has a permanent effect on productivity and long-run economic growth. This approach helps us better understand the transmission channels through which public investment such as that envisaged in the euro area affects long-term growth, and how these may interact with monetary policy.

To study the long-run effects of public investment, we employ DSGE models that feature endogenous growth in TFP. We start by examining the long-run ("scarring") effects of demand- and supply-driven recessions in the face of endogenous growth, to get a sense of the interplay between transitory shocks, productivity and long-run macroeconomic outcomes. Next, we focus on the transmission channel of various types of growth-enhancing public investment and the role of monetary policy. In Box 8, simulations of the growth-enhancing effects of NGEU-funded public investment is shown. Box 9 closes the section with a discussion on the implications of endogenous growth for the monetary and fiscal policy requirements to ensure public debt sustainability.

3.3.1 The scarring effects of demand and supply shocks

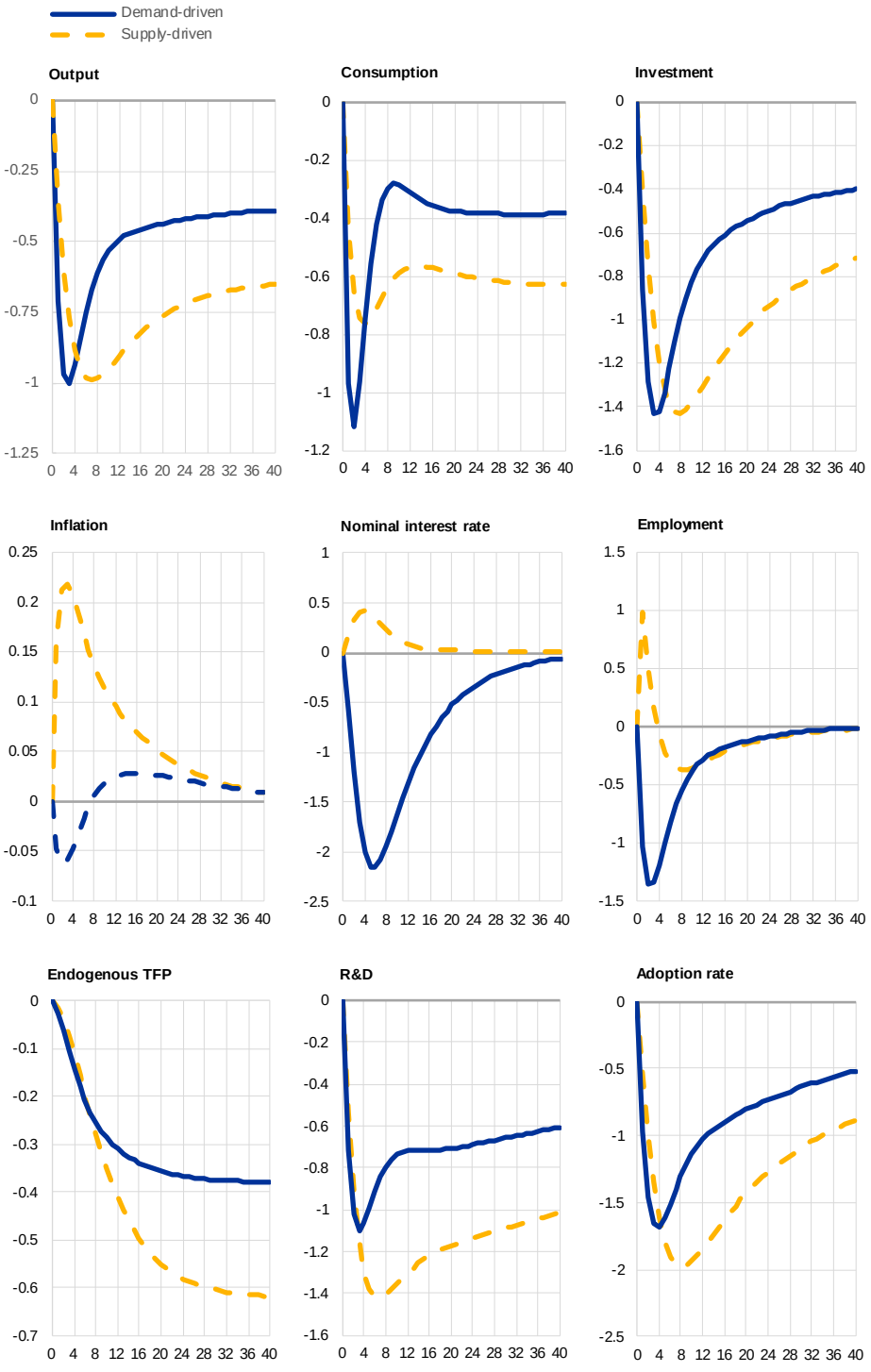
In models featuring endogenous growth, demand- and supply-driven recessions can generate hysteresis effects through a decline in productivity growth that lowers long-run output. To illustrate this, the model and results from Elfsbacka Schmöller (2022) are used, which is a version of the New Keynesian type of DSGE models studied in previous sections yet allows for endogenous growth in TFP. Following Romer (1990), endogenous trend growth arises through the expansion in the varieties of intermediate goods, which occurs in two stages, as in Comin and Gertler (2006). In the "innovation stage", innovators invest in R&D, which ultimately creates new technologies and expands the technology frontier. In the

[74] This section includes contributions by Michaela Elfsbacka Schmoller (Suomen Pankki), Nigel McClung (Suomen Pankki) and Alessandro Notarpietro (Banca d'Italia).

“adoption stage”, the newly invented technologies are adopted by firms, leading to an increase in productivity. Importantly, firms have to undertake costly investment to adopt new technologies. Chart 14 shows the responses to a demand- and supply-driven recessionary shock generated by this model. Both adverse shocks lead to a drop in aggregate output that lowers firm profits. As a consequence, the payoff from both newly invented technologies through R&D and technology adoption falls, and so spending on the latter declines, which results in a deceleration of TFP. Without monetary and fiscal policies aimed at offsetting this, the long-run trend in output permanently falls below its initial path, implying that the economy suffers a permanent output loss. While this effect occurs following both type of shocks, note that inflation falls in the demand-driven recession and rises in the supply-driven recession, which has important implications for the choice of fiscal policy used to combat the recession.

Chart 14 Responses to a demand- and supply-driven recessionary shock under endogenous growth

(y-axes: output, consumption, investment, endogenous TFP and R&D = percentage deviation from initial steady state; inflation and nominal interest rate = percentage deviation from steady state (annualised); employment and adoption rate = percentage deviation from steady state; x-axes: quarters)



Source: Authors' calculations, from Elfsbacka Schmöller (2022).

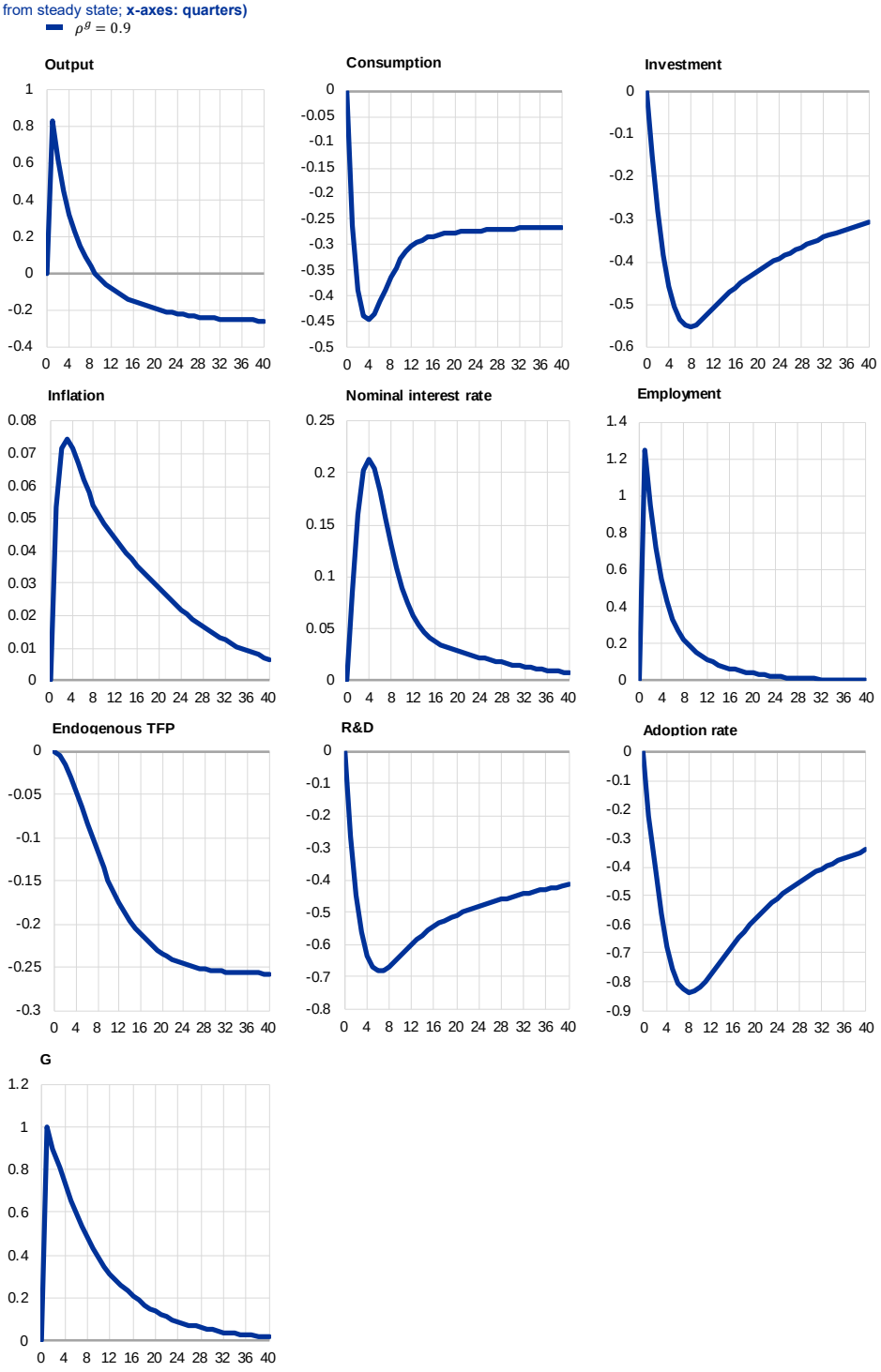
Expansionary government consumption shocks provide a short- to medium run boost to the economy but crowd out technology-enhancing investment.

Chart 15 shows that immediately following an expansionary shock to government consumption aggregate output, employment and inflation rise. Government consumption, however, is subject to crowding-out effects, as private consumption, and investment in physical capital[75] decrease in response to the shock. Moreover, because of the endogenous TFP mechanism, a fall in investment in R&D and technology adoption generates long-run crowding-out effects that cause a deceleration in TFP. Therefore, despite the short-run expansionary effects, a rise in government consumption can weigh on the long-run trend and generate permanent output losses. Note that these results are derived under specific assumptions, in particular that government consumption is wasteful, and agents do not face liquidity constraints. Departing from these assumptions may alter the implications for the long-run effects of government spending under endogenous growth.

[75] The model distinguishes between physical capital and investment in R&D and technology adoption.

Chart 15
Responses to an expansionary government consumption shock

(y-axes: output, consumption, investment, endogenous TFP and R&D = percentage deviation from initial steady state; inflation and nominal interest rate = percentage deviation from steady state (annualised); employment and adoption rate = percentage deviation from steady state; **x-axes: quarters**)



Source: Authors' calculations based on Elfsbacka Schmöller (2022).
Notes: The government consumption shock is scaled to be 1% of pre-shock GDP, has a persistence of 0.9 and is financed by lump-sum taxes.

3.3.2 The impact of growth-enhancing public investment

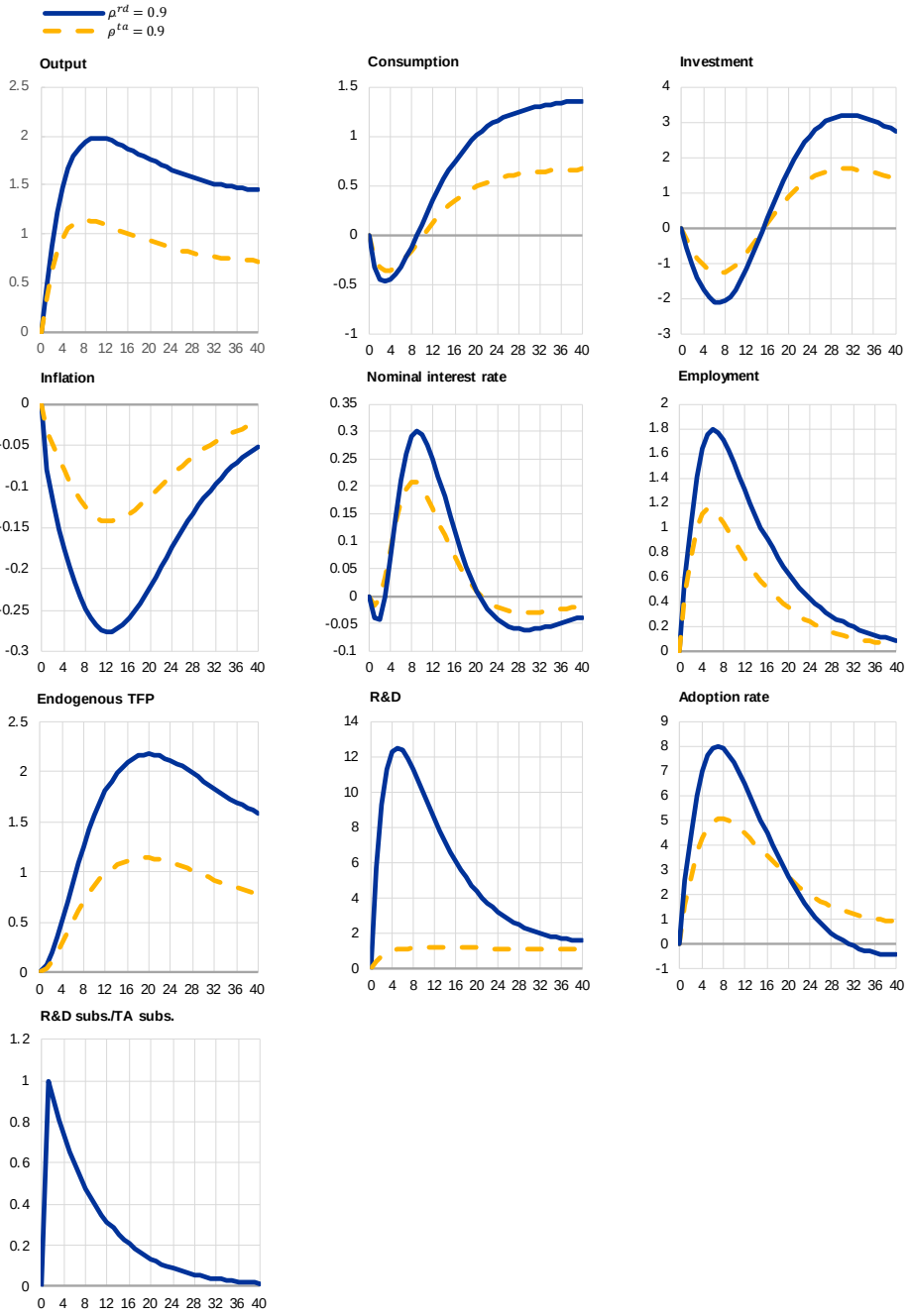
Growth-promoting fiscal policies are effective in raising long-run output, but also in stabilising short-run demand. In the model with endogenous TFP growth of Elfsbacka Schmöller (2022), the government can promote growth by directly targeting technology-enhancing private investment. For example, the government may offer to pay a fraction of innovators' spending on R&D. Chart 16 shows the responses to such a positive shock to fiscal support to R&D.[76] The shock raises the incentives to expand R&D investment, which raises the stock and adoption of new technologies. Consequently, aggregate output rises to a permanently higher level. As before, private consumption and investment fall on impact as they are subject to crowding-out effects. However, these crowding-out effects are only transitory: as employment and income both rise, consumption and investment eventually revert and converge on a new and permanently higher level. Similar outcomes could be achieved if the government were to pay a fraction of firms' technology adoption costs. Rather than expanding the technological frontier through an increase in R&D, which can be a slow-moving process, supporting technology adoption helps raise TFP growth by fostering technology diffusion. In practice, a combination of both types of fiscal support is likely to yield the largest productivity gains. Box 8 shows that an NGEU-funded rise in public investment can actually lead to an immediate crowding-in effect of private consumption and investment.

[76] The fiscal support to R&D is financed by lump-sum taxation.

Chart 16

The effects of an increase in R&D and technology adoption subsidies

(y-axes: output, consumption, investment, endogenous TFP and R&D = percentage deviation from initial steady state; inflation and nominal interest rate = percentage deviation from steady state (annualised); employment and adoption rate = percentage deviation from steady state; x-axes: quarters)



Source: Authors' calculations based on Elfsbacka Schmöller (2022).
Notes: The R&D and technology adoption subsidy shocks are scaled to be 1% of pre-shock GDP, has a persistence of 0.9 and is financed by lump-sum taxes.

Fiscal policies that support innovation can generate large long-run multipliers. Table 1 reports the fiscal multipliers of an increase of 1% of GDP in government consumption, fiscal support to R&D and fiscal support for technology adoption under

endogenous growth. Although the government consumption shock generates the largest multiplier on impact, the cumulative multipliers of fiscal support to innovation are much more sizeable in the medium- to long run, as their impact on the economy builds up slowly over time. In fact, fiscal policies supporting R&D can yield long-run multipliers (that is, after four years) above 1, as they expand the technological frontier. The last column reports the "trend multiplier", which is defined as the percentage change in TFP in the long run relative to its initial level following a transitory fiscal shock. While both types of fiscal policies aimed at supporting innovation can help permanently raise the technology stock and thereby yield positive trend multipliers, government consumption shocks could have a negative trend multiplier due to their long-run crowding-out effect on private spending.

Table 1
Fiscal multipliers under endogenous growth

	Impact multiplier	1 year	2 years	4 years	Peak	Trend multiplier
Government consumption	0.83	0.67	0.54	0.46	0.83 (1 q)	-0.26%
Fiscal support to R&D	0.46	0.99	1.32	1.15	1.35 (10 q)	+1.42%
Fiscal support to technology adoption	0.35	0.69	0.87	0.75	0.88 (9 q)	+0.69%

Source: Authors' calculations based on Elfsbacka Schmöller (2022).
Notes: Fiscal multipliers corresponding to a fiscal shock of 1% of GDP. 1-, 2- and 4-year multipliers are cumulative. The peak multiplier is defined as the maximum cumulative multiplier. The trend multiplier captures the percentage change in long-run TFP relative to its initial level.

Box 8 The effects of NGEU investment on potential output: simulations with an endogenous growth model

Prepared by Rubén Domínguez-Díaz, Samuel Hurtado and Carolina Menéndez-Álvarez (all Banco de España)

To assess the macroeconomic consequences of the NGEU programme on potential output, we develop a real dynamic general equilibrium model with endogenous growth,[77] based on the framework of Atkeson and Burstein (2019). We enrich that economy with endogenous labour supply, extend it to incorporate public capital and calibrate it for the Spanish economy. We then use it to assess the effects of the NGEU programme on output and its components, including the endogenous response of TFP.

The model is comprised of a household sector, non-financial firms and a fiscal authority. The representative household consumes, saves in physical capital and supplies labour elastically. The production side of the economy has two layers of production: intermediate good producers and a producer of final goods that bundles together intermediate goods using a constant elasticity of substitution (CES) production function. Intermediate goods are produced, using capital and labour, by both existing and new firms. An important feature of our framework is that these firms engage in innovative investment (empirically, new firms have been shown to account for a substantial share of innovation investment). Innovation requires ideas produced by a "research good firm" that employs researchers. Once innovative investment has been undertaken it leads, with a certain probability (which we calibrate using data on firm-level dynamics), to improvements in firm-level productivity or the creation of new products which contribute to higher productivity (following Romer, 1990).

[77] The model will be described in more detail in an upcoming Banco de España Occasional Paper: Domínguez-Díaz, Hurtado and Menéndez (2023), "The effect of NGEU investment on potential output in Spain: simulations with the POT-E model".

Therefore, changes in innovative investment affect the dynamics of TFP endogenously. The fiscal authority raises revenue from labour income taxes and can also receive international transfers from the EU. It uses this revenue to fund public investment. In line with the literature, we assume that public capital is productivity-enhancing: a larger stock of public capital allows firms to use their private resources more efficiently. The model is calibrated for Spain using annual macro data from 2000 to 2019 and firm-level data from the Banco de España's Central Balance Sheet Data Office.

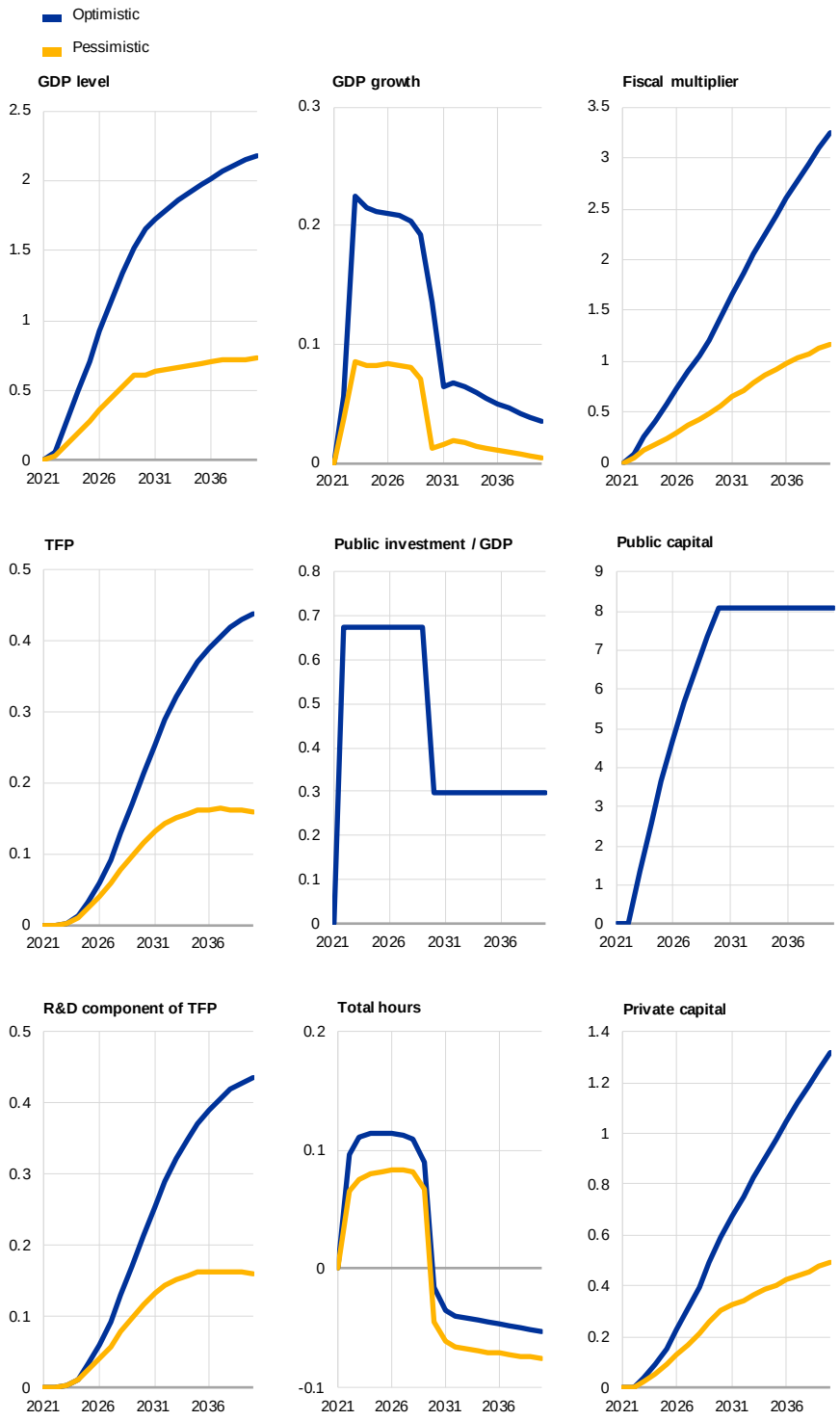
In our simulation exercise, the NGEU programme corresponds to an increase in public investment, spent uniformly over a ten-year horizon.[78] After ten years, we consider that the government covers the depreciation of the newly built public capital permanently (it increases steady-state public investment (covered by an increase in labour income taxes) to maintain public capital at the new level that has been reached after ten years. Regarding the funding of the programme, we assume that international transfers from the EU fully fund the initial increase in public investment, with half of these transfers being non-refundable and the other half taking the form of loans that are paid back uniformly until 2058 through higher labour income taxes.

[78] NGEU funds are also used for other purposes, such as direct transfers to firms. Nevertheless, public investment represents the lion's share of total funds.

Chart A

The effects of an NGEU-funded increase in public investment

(y-axes: percentage deviations from steady state; x-axes: years)



Source: Authors' calculations.
Notes: The optimistic scenario corresponds to a relatively high efficiency of public capital and the pessimistic scenario to relatively low efficiency. "GDP level" and "GDP growth" refer to potential GDP and potential GDP growth respectively.

Chart A shows the implications of raising public investment according to the expenditure scheme described earlier, as predicted by our model. Since there is some uncertainty about the efficiency of public capital in the empirical literature, we provide an optimistic and a pessimistic case, based on different calibration values for the efficiency of public capital. As the figure shows, in this simulation the increase in public investment fosters economic activity, raising GDP growth on average during the first ten years by 0.17 percentage points in the optimistic case, and by 0.07 percentage points in the more pessimistic scenario.

The increase in economic growth comes from different channels. First, there is a direct channel: the increase in public investment raises firms' efficiency, leading to an increase in TFP and therefore aggregate output. Second, indirectly, a larger stock of public capital raises firms' incentives to increase innovative investment, since this becomes more profitable as their productivity increases. As a result of higher innovative investment, TFP endogenously increases further, contributing to output growth. Third, following the same logic, firms also raise private investment, leading to an increase in physical capital. And fourth, the increase in production comes with higher labour demand, leading to higher real wages and a temporary increase in hours worked.

In sum, these simulations with an endogenous growth model calibrated for the Spanish economy suggest that NGEU funds could have significant and persistent positive effects on potential GDP growth, in line with empirical estimations (Cuadrado et al., 2022). A complete assessment of the economic impact of the NGEU programme would require taking into consideration dimensions that are beyond the scope of the current analysis. For example, a more detailed analysis within our framework could account for the sectoral composition of the NGEU funds (Fernández-Cerezo et al., 2023), the heterogeneous efficiencies of different types of public capital (Ligthart and Bom, 2014) or the effects of structural reforms associated with the NGEU programme on GDP growth (Albrizio and Geli, 2021).

3.3.3 Monetary-fiscal policy interactions under endogenous growth

Growth-promoting fiscal policies, while primarily aimed at enhancing productive capacity in the long run, are generally disinflationary in the short term and can therefore help keep inflationary pressures contained during supply-driven recessions. This is illustrated using the model from Cantelmo et al. (2022), which is a slightly different model of endogenous growth than that of Elfsbacka Schmöller (2022). Productivity growth is again realised through private investment in R&D. In addition, the stock of R&D also expands through public investment, which captures positive spillovers that enhance the efficiency of R&D in the private sector.[79] Chart 17 plots the responses to a permanent public investment shock. Three scenarios are considered: (i) a sudden and immediate rise in public investment; (ii) a gradual rise in public investment that takes one year; and (iii) a gradual rise in public investment that takes one year and is combined with an accommodative monetary policy keeping the interest rate fixed during the first three quarters. The rise in public investment raises the productive capacity of the economy, which allows long-run output growth to rise beyond its initial level and also implies an increase in the long-run interest rate. A sudden implementation of the

[79] R&D accumulation (and therefore the stock of R&D) also depends on the market power of firms: more competition in the goods market increases the efficiency of R&D investment.

increase in public investment (the dashed yellow lines) stimulates aggregate demand and supply. The accumulation of public capital makes labour, private physical capital and the R&D stock more productive. Consumption growth immediately starts increasing, while investment does so in the medium term. Investment in R&D rises in the medium term, once the return on investment has increased sufficiently. Inflation goes up moderately, because the rapid implementation of the shock induces a rise in both aggregate demand and aggregate supply. As a result, the policy rate increases and moves towards its higher long-run value.[80] The latter increases in response to a permanent shock, as does the growth rate of output. The sudden implementation entails a strong expectations channel and helps to illustrate the transmission mechanism. In the more realistic case of gradual implementation (the solid blue line), private consumption and investment are exposed to crowding-out effects, as both households and firms have an incentive to save up for investments that are expected to generate higher returns in the future. The increase in productive capacity is less front-loaded compared with the case of sudden implementation. Inflation falls over time as firms' marginal costs decline.[81] Although not examined explicitly here, this latter result suggests that an increase in public investment, even under the empirically plausible scenario of gradual implementation, can be useful in the event of a supply-driven recession to keep inflationary pressures low and support monetary policy in preventing high inflation from becoming a persistent phenomenon.

The short-term crowding-out effects arising from higher public investment can be mitigated through an appropriate monetary-fiscal policy mix. Chart 17 shows that, following gradual implementation of public investment, the initial drop in consumption and inflation is reduced in the scenario featuring accommodative monetary policy (the dotted red line). By keeping the policy interest rate unchanged in the short run, monetary policy allows for a more gradual rise in the interest rate towards its new long-run level and thereby helps to sustain aggregate demand at a higher level compared to the second scenario without monetary accommodation.

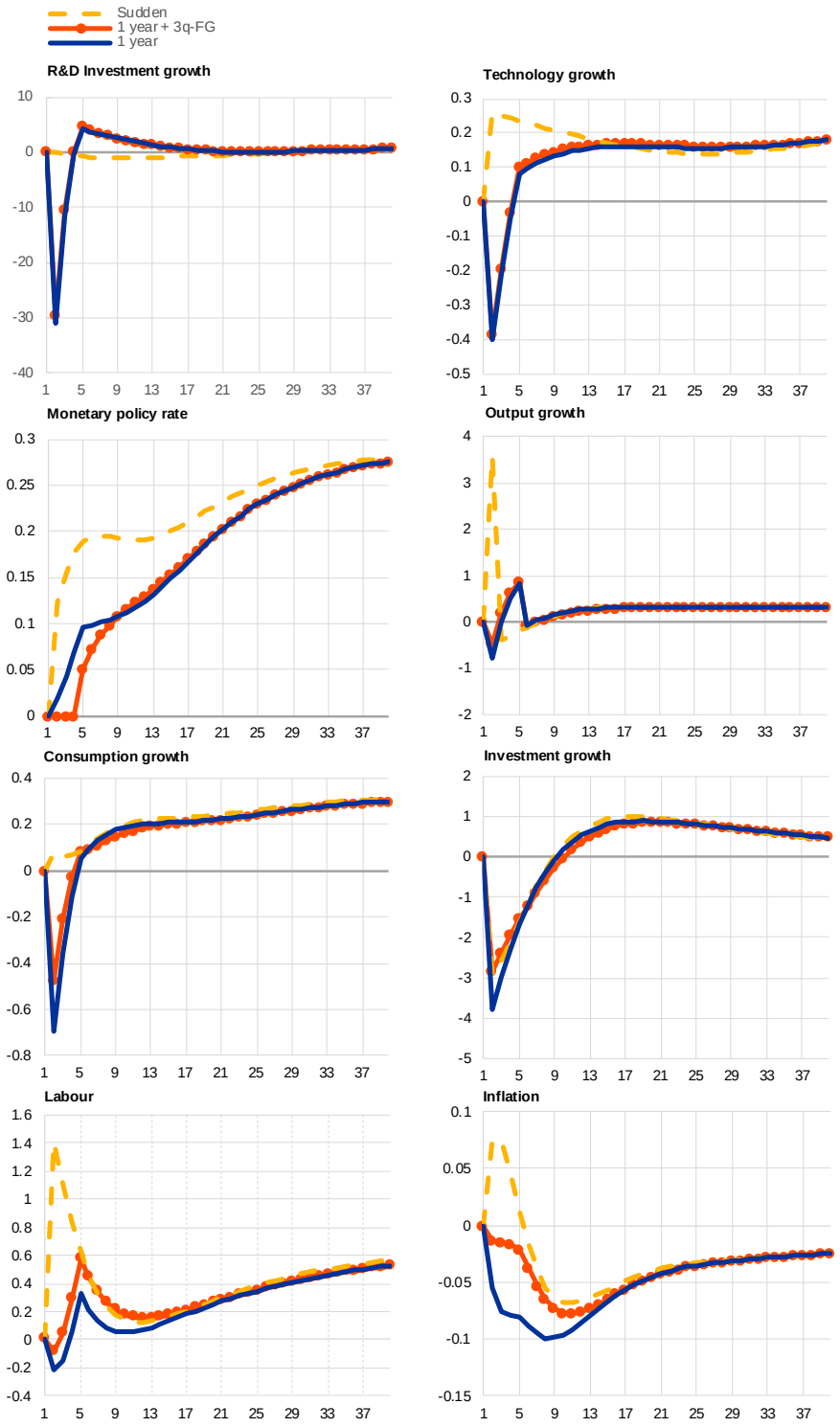
[80] According to the monetary policy rule, when the policy rate deviates from its long-run steady state value it responds to deviations of inflation from the target and to the quarterly gross growth rate of the cyclical (i.e. trend-less) component of output.

[81] Anzoategui et al. (2019) show, in an estimated model with endogenous growth, that there is an inverse relationship between TFP and inflation that works through firms' marginal costs. Similarly, Moran and Queralto (2018) show empirically for the US that inflation falls following an exogenous increase in R&D.

Chart 17

Responses to a permanent increase in public investment under endogenous growth

(y-axes: annualised percentage point deviations from the initial steady state, except for hours worked, which are shown as percentage deviation from initial steady state; x-axes: quarters)



Source: Authors' calculations based on model from Cantelmo et al. (2022).

Box 9 Public debt sustainability under endogenous growth

Prepared by Michaela Elfsbacka Schmöller and Nigel McClung (both Suomen Pankki)[82]

Public debt sustainability and price stability require an appropriate framework for monetary and fiscal policy. Under monetary dominance, in which monetary policy is said to be "active" and fiscal policy "passive" (Leeper, 1991), inflation can be insulated from both fundamental and belief-driven shocks through a commitment by the central bank to stabilise inflation and by the government to ensure long-run debt sustainability. Under fiscal dominance, monetary policy is passive, meaning the central bank does not commit to anti-inflationary policies, while fiscal policy is active, meaning the government does not commit to stabilise fiscal imbalances. Nevertheless, under this regime, fiscal sustainability is still ensured through inflation. This well-known theoretical result about the division of labour between monetary and fiscal authorities depends on the assumption that growth is exogenous.[83] In this box we study how endogenous growth alters the requirements of monetary and fiscal policy arrangements for public debt sustainability.

We use a simple and tractable model that features a mechanism of endogenous TFP growth. The model is an otherwise standard New Keynesian model for a closed economy: households aim to maximise expected lifetime utility, firms produce goods and face a price-setting constraint, the central bank sets the interest rate according to a Taylor rule and the government levies lump-sum taxes to finance its expenditure. The government bond portfolio has a geometrically decaying maturity structure. Aggregate TFP is subject to endogenous growth through R&D (Romer, 1990). In particular, technological growth occurs through entrepreneurial innovation of new product varieties that are used as inputs in production in the spirit of Romer (1990). This implies that changes in demand translate into cyclical movements in R&D and procyclical TFP dynamics.

Under endogenous growth, public debt sustainability can be achieved even if both monetary and fiscal policy are active. To understand why, consider a fiscal expansion (e.g. an increase in government expenditure) that raises the government debt-to-GDP ratio. When fiscal policy is active, the rise in government indebtedness is not met by sufficiently large fiscal consolidation in future and is therefore perceived by households as an increase in their net wealth. Consequently, private consumption rises, which leads to an increase in inflation. An active monetary policy then prompts the central bank to respond aggressively to these inflationary tendencies, which results in an increase in the real interest rate that raises the public's debt servicing costs and further drives up government debt. Under exogenous TFP growth, this vicious cycle of higher debt and higher inflation cannot be a stable equilibrium. However, with endogenous growth, the positive wealth effect induces a rise in output, which in turn raises TFP growth and GDP, thereby lowering and stabilising the government debt-to-GDP ratio. At the same time, the rise in TFP can reduce marginal costs, which in turn lowers expected inflation and, by the Taylor rule, the real interest rate, which then lowers public borrowing costs. Thus, the procyclical dynamics of TFP growth helps to loosen the stability requirements for fiscal policy.

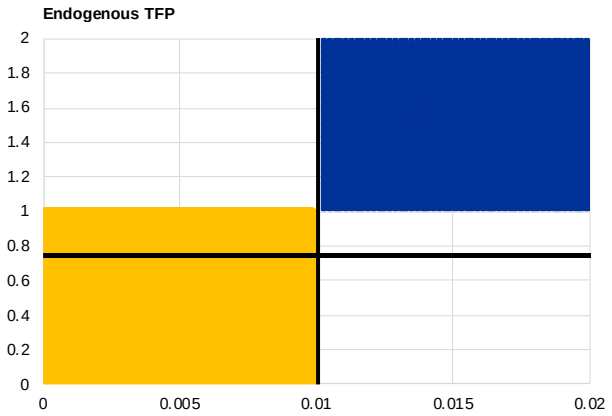
[82] Based on Elfsbacka Schmöller and McClung (2023).

[83] These standard results are derived for a conventional closed economy New Keynesian DSGE model with exogenous technology.

Chart A

Monetary and fiscal policy requirements for equilibrium determinacy and stability under endogenous growth

(y-axis: monetary response to π (ϕ_π) in percentage of GDP; x-axis: fiscal response to public debt (γ) in percentage of GDP)



Source: Authors' calculations, from Elfsbacka Schmöller and McClung (2023).
Note: $r = 0.01$.

Chart A shows how moving from exogenous to endogenous TFP growth affects the monetary and fiscal policy requirements for ensuring a stable and unique equilibrium. The vertical axis measures the monetary policy response to inflation, while the fiscal response to outstanding public debt is measured along the horizontal axis. The solid black lines separate the parameter space into regions in which a particular combination of monetary and fiscal policy yields a stable and determinate equilibrium (the north-east and south-west quadrants), an explosive equilibrium (the north-west quadrant) or an indeterminate equilibrium (the south-east quadrant) under the assumption of exogenous TFP growth. Above the horizontal line, monetary policy is said to be active; below it is passive; on the left of the vertical line fiscal policy is active; on the right it is passive.[84] Under exogenous TFP growth, stability and determinacy is achieved under either active monetary policy and passive fiscal policy or passive monetary policy and active fiscal policy, as in Leeper (1991). The blue and yellow areas show how those regions that admit stable and determinate equilibria change when one moves from exogenous to endogenous growth. In particular, we see that, under endogenous growth, a stable and determinate equilibrium can be achieved when both monetary and fiscal policy are active. Again, the wealth effects generated under active fiscal policy help stabilise public debt through changes in TFP growth and GDP. When fiscal policy is passive, monetary policy needs to be more active than under exogenous TFP in order to achieve stability and determinacy. This is because the presence of endogenous TFP renders aggregate demand more sensitive to changes in expected future output, and a more active monetary policy is needed to avoid an unstable expectational feedback loop.

84 We assume that interest rates also respond to the output gap in Chart A, and therefore the condition for active monetary policy is weaker than the traditional Taylor Principle (see Woodford, 2003). Qualitatively similar results obtain for the case of active fiscal policy when strict inflation targeting is instead assumed.

4 Final remarks

The interaction between monetary and fiscal policies has changed in various ways since the great financial crisis. Finding the right mix between them is of paramount importance for policymakers to ensure macroeconomic stability, particularly during times of economic turmoil, yet often this proves challenging.

In the aftermath of the global financial crisis, many euro area countries faced elevated public debt levels and the ECB was constrained by the ELB. Accommodative monetary policy provided support to economic activity and price dynamics, but inflation remained persistently below target. This led to a debate on whether expansionary fiscal policy, by increasing aggregate demand, could contribute to an increase in inflation. During the pandemic, monetary and fiscal policies were aligned: both were highly expansionary. But the broad change in the macroeconomic and geopolitical environment, brought about by an imbalance between supply and demand during the recovery from the pandemic and worsened by Russia's invasion of Ukraine, fuelled price pressures and pushed euro area inflation to double-digit levels. In this environment, the risk that fiscal and monetary policies once again pull in opposite directions is significant. Fiscal policies that try to limit the adverse distributional effects of high inflation, address long-term sustainable growth, and ensure public debt sustainability may challenge the central bank's efforts to fight high inflation.

The analysis in this report shows that, with an independent monetary policy aimed at bringing inflation back to target in a timely manner, fiscal policy choices can be designed to protect the vulnerable parts of society while still avoiding pulling significantly against the need to tame inflation. This is particularly true if fiscal measures are temporary and targeted, and if priority is given to reforms and public investment in support of potential growth. The latter is particularly effective in reshaping the supply side of our economy in a manner likely to modify its structure positively and permanently.

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6 **Annex:** Description of the models used in Sections 2.2 and 3.2

6.1.1 The medium-scale New Keynesian model: contribution by the representative of Banca d'Italia (Section 2.2)

The model is a standard closed-economy New Keynesian medium-scale DSGE à la Smets and Wouters (2003). The representative household has a standard utility function, separable into consumption (featuring external habit formation) and hours worked. She consumes a non-durable consumption good and invests in two assets: a one-period bond (in zero net supply) paying the policy rate, and physical capital. Investment in physical capital is subject to quadratic adjustment costs. The household supplies labour under monopolistic competition à la Dixit–Stiglitz (1977) and sets the nominal wage taking as given the CES labour demand by firms and paying a quadratic cost à la Rotemberg (1982) for adjusting the nominal wage. Nominal wages are indexed, with corresponding weights summing up to one, to previous-period consumer price inflation and to the central bank's inflation target. The latter is assumed to be constant in all simulations.

As for the supply side of the economy, there are two sectors: one producing the intermediate good, the other producing the final good. Firms in the intermediate sector combine capital and labour, both supplied by the representative household, according to a Cobb–Douglas production function. Firms operate under monopolistic competition à la Dixit–Stiglitz (1977) and set the nominal price of their goods taking the CES demand by the household as given and paying a quadratic cost as in Rotemberg (1982) when adjusting prices. The prices of goods are indexed to the previous-period inflation rate and to the central bank's target with corresponding weights summing up to one. This feature yields a hybrid New Keynesian Phillips curve that links current inflation to current marginal costs, expected inflation, past inflation and the central bank inflation target. The intermediate goods are combined by other firms under perfect competition into a final good used for private consumption, public consumption and investment purposes.

Crucially for our analysis we include a fraction of non-optimising "rule-of-thumb" (ROT) consumers, accounting for 25% of households. Optimising (or "Ricardian") and ROT households have the same type of utility function. ROT households consume their available labour income on a period-by-period basis and have no savings, hence they do not invest in bonds or physical capital.

Monetary policy is described via a standard Taylor rule where the policy rate responds, with inertia, to inflation deviations from the target and output growth.

On the fiscal side, the government can levy distortionary taxes on consumption, capital income and labour income. All these items are kept fixed at their steady-state values in the simulations. On the expenditure side, the government chooses public consumption and targeted transfers to ROT households. It also issues public debt in

the form of one-period government bonds. A fiscal rule dictates adjustments in lump-sum taxes (transfers) to keep the government debt-to-GDP ratio in line with its long-term target. In addition, the government implements – on top of the fiscal rule – an endogenous increase in targeted transfers to ROT households. A simple rule dictates increasing the level of targeted transfers in response to a reduction in output growth. The rule also features an autoregressive term which smooths changes in targeted transfers:

$$TR_t^{ROT} = \rho_{TR} TR_{t-1}^{ROT} - \varphi_{TR}\left(\frac{y_t}{y_{t-1}} - 1\right)$$

where TR_t^{ROT} are ROT-targeted transfers (which are set to 0 in steady state) and $0 < \rho_{TR} < 1,\ \varphi_{TR} > 0$ are parameters. The latter are calibrated to ensure that, in response to the shock considered in the simulations reported in the text, the consumption profile of ROT households is broadly equalised to the one of Ricardian households.

6.1.2 The EA DSGE model: contribution by the representative of Banca d'Italia (Section 3.2)

The model is a three-region large-scale New Keynesian dynamic general equilibrium model which includes two euro area regions (one labelled "Home", calibrated to a relatively small-size economy, and the other assembling the rest of the euro area, dubbed "REA") and the rest of the world ("RW"). The model is akin to the Eurosystem EAGLE (see Gomes et al., 2010). For a detailed illustration, see Burlon et al. (2017).

The euro area is a monetary union, so Home and REA share the same currency and monetary authority. The monetary authority can resort to both standard and non-standard monetary policies, the latter including forward guidance and asset purchases. It sets the nominal interest rate according to euro area- wide variables (a standard Taylor rule holds) when it does not deliberately enact non-standard monetary policy measures. The presence of RW outside the euro area allows us to assess the role of the nominal exchange rate and extra-euro area trade for the transmission of euro area shocks.

The model features country-specific fiscal policies; on the expenditure side, the public-sector budget features lump-sum transfers, public consumption and public investment in infrastructure. On the revenue side, there are distortionary taxes on labour income, capital income and consumption. Public debt is stabilised through a fiscal rule adjusting lump-sum transfers to achieve the desired debt target.

Euro area firms can sell their final investment goods not only to domestic households, but also to the domestic public sector. The former exploits investment goods to accumulate "private" physical capital, the latter to accumulate "public" capital. Public investment is an exogenous variable set by the fiscal authority. Crucially, domestic public capital enters the production of intermediate tradable and

non-tradable goods jointly with capital and labour supplied by domestic households. Public capital is common to both sectors. Firms take public capital as given when choosing their optimal demand for private capital and labour. Public capital does not provide any pecuniary return, but increases productivity of the private inputs and, thus, their returns.

The model also features financial segmentation à la Chen et al. (2012), which allows us to relax the well-known “Wallace neutrality” and make financial assets an imperfect substitute so that sovereign bond purchases by the monetary authority have real effects in the model. In each region of the euro area there are two types of households: “restricted” and “unrestricted”. Restricted households can invest only in domestic long-term sovereign bonds and, because they are owners of domestic capital producers (jointly with domestic unrestricted households), in domestic private physical capital. The purchase of long-term government bonds by the monetary authority reduces long-term interest rates and therefore induces restricted households to increase consumption and investment via the standard intertemporal substitution effect. Unrestricted households (1) have access to domestic short-term private bonds and long-term sovereign bonds; (2) trade a riskless private bond with RW households, and; (3) invest in physical capital, because they own domestic capital producers. The latter accumulate private physical capital by demanding final investment goods subject to quadratic adjustment costs on investment change. They rent out capital to the domestic firms producing intermediate goods. They maximise profits with respect to capital and investment taking prices as given, and evaluate returns according to a weighted average of restricted and unrestricted households' stochastic discount factors (where the weights reflect the corresponding shares in the population). Net revenues are rebated in a lump-sum way to domestic restricted and unrestricted households according to their corresponding shares.

Households consume a final good that is a composite of intermediate non-tradable and tradable goods. The latter are domestically produced or imported. All households supply differentiated labour services to domestic firms and act as wage setters in monopolistically competitive labour markets by charging a mark-up over their marginal rate of substitution between consumption and leisure. On the production side, there are perfectly competitive firms that produce two final goods (consumption and investment) and monopolistic firms that produce intermediate goods (firms are owned by domestic unrestricted households). The two final goods are sold domestically and produced combining all available intermediate goods using a CES production function. The two resulting bundles can have different compositions. Intermediate tradable and non-tradable goods are produced combining domestic public capital, private capital and labour. The latter two production factors are assumed to be mobile across sectors. Intermediate tradable goods can be sold domestically and abroad. Since intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We also assume that markets for tradable goods are segmented, so that firms can set a different price for each of the three markets. In line with other dynamic general equilibrium models of the euro area (see, among others, Christoffel et al., 2008 and Gomes et al., 2010), we include adjustment costs on real and nominal variables, ensuring that consumption, production and prices react in a gradual way to a shock.

On the real side, habits and quadratic costs prolong the adjustment of consumption and investment respectively. On the nominal side, quadratic costs make wages and prices sticky.

6.1.3 EAGLE6: contribution by representatives of the ECB and Banco de Portugal (Sections 2.2 and 3.2)

The EAGLE model is a multi-country dynamic general equilibrium model of the euro area within the world economy. It was developed as an ESCB project by a team composed of staff from the Bank of Italy, the Bank of Portugal and the ECB (Gomes et al., 2010; Gomes et al., 2012). The model shares the same theoretical setup as the ECB New Area-Wide Model (Christoffel et al., 2008). It is a large-scale, micro-founded model of a monetary union that consists of an open economy version of the New Keynesian paradigm.

In the version of the model used here, the world economy consists of six blocs. Five are members of a monetary union, the euro area (Germany, France, Italy, Spain and the rest of the euro area), and as such share a common nominal exchange rate and a common nominal interest rate. The central bank sets the domestic short-term nominal interest rate according to a Taylor-type rule by reacting to consumer price inflation and output growth, both defined at the euro area level. The remaining bloc, the rest of the world, has its own nominal interest rates and nominal exchange rates.

In all blocs, fiscal policy is conducted at the country level. The fiscal authority in each country sets public expenditure, lump-sum taxes, labour and capital income taxes and consumption taxes. Government spending on consumption and investment goods is specified as a fraction of steady-state nominal output, as is standard in the literature. Moreover, in each country, the public debt is stabilised through a fiscal rule that induces endogenous adjustment of lump-sum taxes. The fiscal bloc allows for government consumption and investment to play a non-trivial role in affecting the optimal decision-making of the private sector (as in Leeper et al., 2010, Coenen et al., 2013, and Clancy et al., 2016). More specifically, households are assumed to derive utility from the consumption of a composite good consisting of private and public consumption goods. It is assumed that government capital stock affects the production process. A remaining part of public expenditures is considered wasteful.

All regions trade with each other at the level of intermediate goods, with a matrix of bilateral trade flows based on recent historical averages. International asset trade is limited to non-contingent nominal bonds denominated in US dollars.

In each country there are two types of firms. One produces final non-tradable goods under perfect competition using domestic tradable goods, imported tradable goods and non-tradable goods. Final goods can be used for private consumption and for private investment. There is also a final public good that is fully biased towards domestic non-tradable intermediate goods. Intermediate goods are produced by an array of firms under monopolistic competition using domestic labour and capital, combined according to a Cobb–Douglas technology. The market power implies that

firms set nominal prices and charge a mark-up over marginal costs. Nominal prices are sticky.

There are two types of infinitely lived households in each country: Ricardian and non-Ricardian. Households gain utility from consuming and suffer disutility from working. Ricardian households have access to financial markets, where they buy and sell domestic government bonds and internationally traded bonds denominated in US dollars (as well as a euro-denominated bond traded within euro area blocs), accumulate physical capital, rent their services to firms, supply labour and hold money for transactions purposes. Non-Ricardian households only have access to money balances, which means their ability to intertemporally smooth consumption is limited.

6.1.4 EAGLE-Ireland: contribution by the representative of the Central Bank of Ireland (Section 3.2)

EAGLE-IREL corresponds to the Fiscal EAGLE model (Clancy et al., 2016), where the world economy is composed of four blocs: Ireland, the rest of the euro area, the US, and the rest of the world. The fiscal extension of EAGLE extends its original version (Gomes et al., 2012) in several dimensions. First, it makes it possible to study the effects of government consumption and investment separately. Second, it takes into account the import content of government spending, an important feature for small open economies. Third, government consumption enters directly into the household utility function, that is, changes in government consumption directly affect optimal private consumption decisions. Finally, public investment is not wasteful, since it contributes to public capital and enhances the private sector's production function. For all other economic interactions, the Fiscal EAGLE model is identical to the original EAGLE. For a more detailed description of the model structure, see the section on EAGLE6.

6.1.5 EAGLE-Slovakia: contribution by the representative of Národná banka Slovenska (Section 3.2)

EAGLE-SK corresponds to the Fiscal EAGLE model (Clancy et al., 2016), where the world economy is composed of three blocs that are members of a monetary union, the euro area: Slovakia, Germany, the rest of the euro area (REA), and a fourth bloc, the rest of the world. The blocs that compose the euro area share a common nominal exchange rate (against the rest of the world) and a common nominal interest rate. In the model, the world economy consists of four blocks. Three blocks are members of a monetary union, the euro area (Slovakia, Germany, and the rest of the euro area (REA)), and as such share a common nominal exchange rate and a common nominal interest rate. For a more detailed description of the model structure, see the section on EAGLE6.

6.1.6 The POSA model: contribution by the representative of Nationale Bank van België/Banque Nationale de Belgique (Section 3.2)

POSA is a closed economy model originally developed by Rannenberg (2021). The model has nominal wage and price rigidities, real rigidities like investment adjustment costs and habit formation as in Smets and Wouters (2007). However, following Bernanke et al. (1999) and Christiano et al. (2014), capital accumulation is conducted by an entrepreneurial sector which funds its capital stock via its own net worth and loans from financial intermediaries, subject to a costly state verification problem. Financial intermediaries collect deposits from households. Furthermore, there is a fiscal sector levying distortionary labour, capital and consumption taxes as well non-distortionary lump-sum taxes on households and firms. Government expenditure consists of government consumption and government investment. In the estimated version of the model, all expenditure types and tax rates respond to economic activity and debt via estimated fiscal rules, except for except profit tax rates. Finally, households have Preferences Over Safe Assets (POSA), which in the model are the sum of government debt and financial intermediary deposits. Rannenberg (2019) and (2021) show that POSA can eliminate the forward guidance puzzle and attenuates Ricardian effects in response to permanent government consumption changes, implying a higher fiscal multiplier than without POSA, especially during periods when monetary policy is constrained by the effective lower bound. The reason for these effects can be gathered from the linearised consumption Euler equation, which is given by

$$\widehat{\lambda_t} = \theta\left(E_t\lambda_{t+1} + \widehat{R_t} - E_t\Pi_{t+1}\right) - (1-\theta)\sigma_b \frac{y}{\widehat{b_{tot,t}}}\widehat{b_{tot,t}}$$

where $\widehat{\lambda_t}$, $\widehat{R_t} - E_t\Pi_{t+1}$ and $\widehat{b_{tot,t}}$ denote the marginal utility of consumption, the ex ante real interest rate and total real safe assets, respectively. The case without POSA is represented by $\theta = 1$. For $\theta < 1$, the discounting effect attenuates the effect of future periods' marginal utility of consumption $\widehat{\lambda_{t+1}}$ on $\widehat{\lambda_t}$, thus current consumption. This attenuation means that current consumption potentially depends much less on the future real interest rate path and (for permanent government expenditure shocks) the consumption level in the new steady-state.

The euro area version of the model is described in Rannenberg (2019) (see Section 5 and Appendix J). It is estimated on euro area macroeconomic data (the "standard" seven series"), fiscal data (taxes, government consumption and investment and the government deficit) and data on short term interest rate expectations, using Bayesian methods. The data on interest rate expectations and the deficit are helpful to identify the POSA-related parameters θ and σ_b. One important difference in the model used here compared with Rannenberg (2019) is the assumption that there is a productive public capital stock, while in Rannenberg (2019) public investment does not differ from public consumption.[85] In particular, the production function of firms is now given by

[85] In that paper the separation was only made to account for the very different time series properties of government consumption and investment data.

$$Y_{f,t} = exp(\varepsilon_{a,t})(TFP_{t-1}N_{f,t})^{1-\alpha-\alpha_E-\alpha_P}(TFP_{t-1}N_{E,f,t})^{\alpha_E}\widetilde{K_{f,t}^{\alpha}}\widetilde{K_{P,f,t}^{\alpha P}} - TFP_{t-1}\Phi$$

6.1.7 The EA-BDF model – contribution by the representatives of the Banque de France (Section 3.2)

The EA-BDF model (Aldama et al., 2022) extends FR-BDF, the large-scale semi-structural model for France used by the Banque de France (Lemoine et al., 2019) with a medium-scale model for the rest of the euro area: STREAM (Semi-sTructural Rest of Euro Area Model). STREAM too is a semi-structural model inspired by the FRB/US approach: it uses the polynominal adjustment costs (PAC) framework and includes explicit expectations that can be either VAR-based (VBE), model-consistent (MCE), or hybrid (HYB). We have made several simplifications in STREAM compared with FR-BDF, notably with respect to the accounting framework, which is less detailed. First, on the supply side, potential output is exogenous and a New Keynesian price Phillips curve based on the unemployment gap determines inflation (the GDP price deflator). We do not explicitly model the labour market or the price-wage loop: an Okun's law relates unemployment and output gaps. Second, on the demand side, we simply relate nominal income of households to nominal GDP with a reduced-form error-correction equation. Then, we relate household consumption to permanent income and the interest rate, with a role for current demand in the short run. The main drivers of total investment are demand and the expected real cost of capital, based on the sovereign long rate. As in FR-BDF, the government uses a fiscal rule on social transfers to stabilise its budget balance-to-GDP ratio towards a level consistent with a target for the debt-to-GDP ratio. Both REA and FR blocks are connected through trade and share a common monetary policy.

Regarding the trade block, we model both consolidated and internal REA exports and imports (volume and deflators). Consolidated exports and imports depend on foreign/internal demand and relative price, through error-correction models. We relate internal imports (volume and deflators) to REA demand and prices; we assume internal exports equal to internal imports. Finally, the euro effective exchange rate and euro/dollar exchange rate equations (real UIP conditions) are common to both models and the REA term structure is similar to that of France, applied to a weighted average of the four biggest REA countries' sovereign bond rates.

There is no public capital in the production function of both blocks; hence, we cannot account for supply-side effects of public investment shocks. To capture these, we add exogenous TFP shocks calibrated to the size of the shock on capital and with an elasticity of output to public capital in line with those found in the empirical literature (Bom and Ligthart, 2014).

Compared with DSGE models, our semi-structural models (both FR-BDF and EA-BDF) generally differ in terms of elasticity of consumption to the real interest rate, which is much lower than in DSGE models. Therefore, monetary policy mainly transmits to the economy through the effect of the real cost of capital on investment

and the effect of nominal exchange rate movements on real net exports, rather than through private consumption and intertemporal substitution effects.

6.1.8 ECB-BASE: contribution by representatives of the ECB (Sections 2.2 and 3.2)

ECB-BASE is a semi-structural macroeconomic model of the euro area developed for use in macroeconomic projections, as well as for policy simulations (see Angelini et al., 2019 for a description). The model features optimising behaviour by households and firms and a comprehensive representation of monetary policy transmission channels. As documented in Bańkowski (2023), the model also embeds a well-developed fiscal sector, which provides a meaningful role for fiscal policy and makes it well suited for analysing fiscal policy questions in the euro area. The blocks in the ECB-BASE model are drawn on the experience of other semi-structural models at other policy institutions. These are, most notably, the FRB/US model of the Federal Reserve Board described in Brayton and Tinsley (1996) and the LENS model of the Bank of Canada documented in Gervais and Gosselin (2014).

The applied version of the model embeds backward-looking expectations, which tilts the power from monetary policy to fiscal policy compared to a DSGE model with forward-looking expectations. Backward-looking expectations result in the absence of Ricardian equivalence. In this context, economic agents do not internalise any future consolidation needs resulting from a fiscal stimulus. Accounting for anticipated future consolidation would weaken its effects. Similarly, financial market participants in the model are insensitive to any information announced on the future path of interest rates or other monetary policy measures known in advance. This eliminates the power of forward guidance present in DSGE models that weakens the potency of monetary policy, which also tends to work through anticipation channels.

The fiscal block in ECB-BASE features a high degree of disaggregation on both revenue and spending sides of the budget, to an extent that enables careful exploration of the information contained in government finance statistics. In addition, for selected variables that comprise final government demand (government consumption and investment), not only nominal values are modelled but also volumes and prices. Finally, several items describing the government labour sector complement the set of fiscal model variables. While this approach brings some complications to the model set-up, it comes with a range of advantages; notably, the high degree of granularity allows for a wide range of fiscal shocks, which helps analyse specific macroeconomic policies.

The design of the new ECB semi-structural model is geared towards its main two applications: providing input to macroeconomic projections and conducting policy simulations or counterfactual scenarios. The applications for fiscal policy analysis allow the model to be used for relevant policy questions, such as assessing alternative fiscal rules, evaluating fiscal policy measures or fiscal forecasting.

6.1.9 BoGGEM: contribution by the representatives of the Bank of Greece (Section 3.2)

The BoGGEM model is a micro-founded dynamic stochastic general equilibrium (DSGE) model that includes the main characteristics commonly shared among structural models used by most central banks and international institutions, as well as some features that are important to adapt the model to the Greek economy.[86]

In particular, the domestic economy is modelled as a small open economy that belongs to a currency area in the sense that the nominal exchange rate is exogenous and there is no monetary policy independence. In the absence of autonomous monetary policy, the domestic nominal interest rate is determined by an exogenously given risk-free foreign nominal policy interest rate and a risk-premium component. The domestic economy consists of a large number of households, firms and a government. There are two types of household, differing in their ability to participate in asset markets. The first has access to the financial markets and can transfer wealth intertemporally by trading bonds and accumulating physical capital; the second type is assumed to be liquidity-constrained in the sense that it cannot lend or borrow. Both receive labour income by working in the private and public sector.

With regard to the labour market in the private sector, households supply differentiated labour services and there are labour unions that act as wage setters in monopolistically competitive labours markets. As a result, private sector wages can deviate from the marginal product of labour due to labour unions' bargaining power. Concerning the production sector, the model features monopolistically competitive firms that produce tradable and non-tradable differentiated intermediate goods. Firms in the tradable sector sell their output domestically and in the rest of world (recorded as exports), while firms in the non-tradable sector sell their output only domestically. There are also importing firms that import intermediate goods from abroad and operate under monopolistic competition. Once differentiated, the imported intermediate goods are then supplied as inputs to the production of final goods. Firms set prices of their differentiated output according to the Calvo-type scheme with partial indexation. All types of intermediate goods are used as inputs to produce consumption and investment final goods. The latter are produced by perfectly competitive firms and are sold to domestic households and the government.

The model includes a relatively detailed fiscal policy block. In particular, the government hires labour and combines public consumption and public employment to produce public goods that provide direct utility to households. It levies taxes on consumption, income from labour and capital earnings, as well as lump-sum taxes, and issues one-period government bonds in the domestic bond market and the international markets. Total tax revenues together with the issue of new government bonds are used to finance public purchases of goods and services, public investment, government transfers and public sector wages. Public investment is used for the accumulation of public capital that induces production externalities to

[86] For details of the main features of the model, see Papageorgiou and Vourvachaki (2017) and Papageorgiou (2014).

the private sector, thereby affecting the productivity of the private sector's factors of production, namely capital and labour. The model also features sovereign risk premia that are positively correlated with government indebtedness, introducing a sovereign risk channel through which sovereign default risk is transmitted to the real economy.

Finally, the model includes a number of nominal and real frictions, such as habit formation in consumption, investment adjustment costs and variable capital utilisation that have been empirically identified as playing an important role for the transmission of structural shocks.

The model is calibrated for the Greek economy at a quarterly frequency. The values of the structural parameters are set as in Papageorgiou and Vourvachaki (2017) and Papageorgiou (2014). The exogenous fiscal policy instruments are set to equal their average values in the data over the period 2017-19.

6.1.10 **Latvia's fiscal model**: contribution of the representative of Latvijas Banka (Section 3.2)

Latvia's fiscal model (Bušs and Grüning, 2023) is an estimated fiscal DSGE model for Latvia – a small open economy in a monetary union.

Regarding its fiscal block, the key government expenditure elements comprise utility-enhancing public consumption, public investment that increases private productivity, and transfers to two types of households: optimising and hand-to-mouth. Unemployment benefits are modelled separately from other transfers due to their cyclicality and their role as an outside option for workers in the wage bargaining process. In the case of public investment and public consumption, a part of public goods is imported from abroad. The revenue side is composed of consumption taxes, labour income taxes, social security contributions by both employers and employees, capital income taxes, and lump-sum taxes (levied solely on optimising households).

The model allows for foreign holdings of domestic public debt - a feature that is not yet standard in the literature and alters the model behaviour markedly; in particular, it raises fiscal multipliers. Foreign ownership of public debt is empirically relevant for Latvia, as the majority of the country's public debt is foreign-owned. The domestic government bond yield is driven by government bond-specific exogenous shocks and deviations in the public debt-to-GDP ratio; as such, the higher the public debt, the more costly it is for the government to sustain it. In its default specification, fiscal rules describe the reaction of fiscal authorities to deviations in the debt-to-GDP ratio from its targeted level and to the output gap.

The model is rich beyond the fiscal block. In particular, it contains a financial frictions block whose importance in the Latvian economy is documented by Bušs (2016). The financial frictions channel amplifies the fiscal multipliers, especially the effects of the capital income tax shock.

In addition, the model includes a labour market block with search-and-matching frictions and procyclical wages. Real wages in Latvia have been strongly procyclical historically; a standard Nash wage bargaining scheme has difficulty in fitting such data. Therefore, the standard mechanism is altered by endogenising the workers' outside option. This means the model is better able to capture the dynamics of unemployment and wages, hence also of unemployment benefit expenditure and labour tax revenues. Wage procyclicality dampens the reaction of the real economy to fiscal shocks, since this channel works as a procyclical labour cost to firms.

The core block is similar to Adolfson et al. (2008). There are three final goods - consumption, investment, and exports - which are produced by combining the domestic homogeneous good with specialised imports for each type of final good. Households maximise expected lifetime utility from a discounted stream of consumption, subject to habit formation. Households own the economy's stock of physical capital. They determine the rate at which the capital stock is accumulated and the rate at which it is utilised. Households also own the stock of net foreign assets and determine the rate of stock accumulation. Monetary policy is conducted exogenously, due to Latvia being a member of the euro area accounting for a small share (~0.3%) of the GDP of the overall GDP of that area. The foreign economy is modelled as an SVAR model in euro area output, inflation, nominal interest rate and unit-root technology growth, as well as foreign demand, competitors' export price and nominal effective exchange rate. The model economy has one source of exogenous unit-root growth (neutral technology growth), which is identified using euro area data in the foreign economy block.

The model is estimated to the Latvian quarterly data for the period from the second quarter of 1995 to the third quarter of 2018 using a rich dataset: 28 observables, nine of which are fiscal time series.

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Table A – Model characteristic

	EAGLE6 model	EAGLE-SK model	EAGLE-IREL model	EA DSGE model	POSA model	BdF model	ECB-BASE model	BoGGEM	Latvijas Banka fiscal DSGE model
Open vs closed economy	Open	Open	Open	Open	closed	Open-economy	Open	Small open economy	Open
Blocs and sizes	DE (0.12), FR (0.09), IT (0.06), ESP (0.04), REA (0.09), RoW (0.6)	SK (0.11%), DE(5.24%), REA(12.74%), RW(81.91%)	IE (0.3%), REA(19.7%), US(31%), RW(49%)	Home (2.6% of world GDP), REA (18.6%), RW (78.8%)	1	Two blocks of the euro area: France (20%) and rest-of-euro area (80%)	Euro area, RoW is exogenous	Greece, RoW is exogenous	Latvia, REA/ROW is exogenous as Latvia forms 0.3% of EA GDP.
Share of HtM/liq. constrained households/other	25% all blocs	SK(50%), DE(25%), REA(25%), RW(25%)	25% all blocks	25% restricted households	none	nd	different propensities to consume from different income classes	0.4	20% (estimated with DSGE, down from prior 35%)
Sticky prices	Yes	Yes	Yes	Yes	yes	Yes	Yes	Yes	yes
Type	Calvo	Calvo	Calvo	Rotemberg	calvo	Polynomial adjustment costs	Reduced-form hybrid NKPC	Calvo	Calvo
Indexation (parameter)	0.5 all blocs	SK(0.5), DE(0.5), REA(0.5), RW(0.7)	IE (0.5), REA(0.5), US(0.5), RW(0.5)	0.75 (past inflation)	0.1699	nd	0.39 (past inflation)	0.256 (past inflation)	Domestic good: estimated 0.21 down from prior 0.5 (previous quarter inflation)
Frequency of adjustment	DE 0.85=6.7Q; FR 0.85=6.7Q; IT 0.8=5Q, ESP 0.8=5Q, REA 0.8=5Q, RoW 0.75=4Q	SK(0.5=2q), DE(0.9=10q),REA(0.9=10q),RW(0.79=4.75q)	IE (0.75), REA(0.75), US(0.75), RW(0.75)	Home T: 9Q; Home NT: 19Q; REA T: 10Q; REA NT: 18Q; RW T in H and REA: 4Q	every 7.5 quarters, calvo parameter: 0.8664	nd	nd	0.7059 in domestic markets, 0.6491 in foreign markets	domestic good: estimated 0.69 (3.2Q) down from prior 0.75
Price Phillips curve slope (=coefficient on percentage deviation of marginal cost in the linearized Phillips Curve)	-	-	-	-	-	-	-	-	-
Sticky wages	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Real wage rigidities. Real wages respond sluggishly to labor market conditions	Yes
Type	Calvo	Calvo	Calvo	Rotemberg	Calvo	Reduced-form hybrid NKPC	Reduced-form hybrid NKPC	-	Nash bargained wages depending on labour market conditions subject to (estimated) inertia
Indexation (parameter)	0.75 all blocs	0.5	0.75	0.75 (past inflation)	0.2461	nd	0.14 (on past inflation)	-	Not explicitly indexed to inflation
Frequency of adjustment	0.75 all EA blocks, 0.75 RoW	SK(0.75=4q), DE(0.85=6.6q), REA(0.85=6.6q),RW(0.78=4.5q)	IE (0.75), REA(0.75), US(0.75), RW(0.75)	Home: 9 q; REA: 6 q; RW: 6 q	every 10 quarters, Calvo parameter 0.8980		nd	-	resulting in relatively flexible wages

	EAGLE6 model	EAGLE-SK model	EAGLE-IREL model	EA DSGE model	POSA model	BdF model	ECB-BASE model	BoGGEM	Latvijas Banka fiscal DSGE model
Wage Phillips curve slope (=coefficient on percentage deviation of the wedge between the real wage and the MRS in the linearized Phillips Curve)	-	-	-	-	-	-	0.5 (on measure of wage gap)	-	-
Import content of gov. consumption	0	SK(2%), DE(1%),REA(1.23%),RW(0.85)	IE (2%), REA(1.23%), US(0.85%), RW(0.996%)	0 (fully biased towards nontradables)	-	Yes	Yes	No	0.13
Elast. subst. btw. domestic and imported	-	2.5	2.5	-	-	FR: -1.10 // REA: -1.49	nd	-	estimated 1.1
Bias toward domestic goods	-	SK(0.51),DE(0.72),REA(0.72), RW(0.65)	IE (0.23), REA(0.73), US(0.65), RW(0.79)	-	-	FR: 0.89 // REA: 0.90	nd	-	
Import content of gov. investment	0	SK(1%), DE(0.4%),REA(0.4%),RW(0.4%)	IE (1%), REA(0.4%), US(0.4%), RW(0.4%)		-	Yes	Yes	No	0.45
Elast. subst. btw. domestic and imported	-	2.5	2.5	1.5	-	FR: -1.10 // REA: -1.49		-	estimated 1.2
Bias toward domestic goods	-	SK(0.37),DE(0.51),REA(0.53), RW(0.42)	IE (0.43), REA(0.54), US(0.46), RW(0.59)	0.68 (Home), 0.59 (REA)	-	FR: 0.78 // REA: 0.67		-	
Complementarity between priv. and gov. consumption ?	Yes	Yes	Yes	NO	NO	No	No	No	Yes
Elast. of substitution	0.30 all blocs	SK(0.2),DE(0.33),REA(0.29), RW(0.33)	IE (0.2), REA(0.29), US(0.33), RW(0.33)	-	-	Nd	nd	-	estimated 0.88
Quasi-share of gov. consumption in the aggregator	0.25 all blocs	SK(0.25),DE(0.2),REA(0.25), RW(0.2)	IE (0.20), REA(0.25), US(0.20), RW(0.20)	-	-	Nd	nd	-	estimated 0.07 down from prior 0.15
Public capital depreciation rate	0.025 all blocs	0.025	0.025	0.025 (quarterly)	0.025 quarterly	5% annually	0.025 (quarterly)	0.0107 (quarterly)	same as private, 0.0285
Public capital enters priv. sector production function?	Yes	Yes	Yes	Yes	yes	Indirectly, through TFP	Yes	Yes	yes, as a CES aggregate
Type of production function	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas with fixed costs of production	CES for FR ; nd for REA	Cobb-Douglas	Cobb-Douglas	public capital enters a CES aggregate of private and public capital
Weight	0.05 all blocs	0.05	0.05	0.07	Elasticity of "gross" output (disregarding fixed costs) w.r.t. public capital: 0.0412. Elasticity of output after accounding for fixed costs: 0.081	0.1	nd	0.0433	15% share in total capital bundle; elasticity of substitution b/w private and public capital estimated 1.57 (moderate substitution)
Public debt to GDP ratio in steady state	DE 60%; FR 100%; IT 130%; ESP 100%; REA 65%; RoW 60%	0.6	0.6	Home: 130%. REA: 100%. Almost entirely short-term debt.	66%	60%	0.85	1.37	0.3

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