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1 Introduction

The Maastricht Treaty was designed to ensure a rigid separation between monetary and fiscal policy. The Treaty is the legal consequence of the belief that in an asymmetric federation, with a single monetary policy authority and nineteen fiscal authorities, macroeconomic stability is best achieved by a combination of a credible and independent central bank targeting price stability, and fiscal rules setting public deficit and public debt limits.

Implicit in this design is the idea that active coordination between monetary and fiscal policy is not necessary to pin down the price level provided that all authorities follow the rules. This design provides a sort of passive coordination whereby monetary policy always controls the price dynamics, and hence fiscal authorities are constrained to always balance their debts via surpluses. This is a policy framework in which monetary policy is active while fiscal policy is constrained to be passive, to use the influential classification of Leeper (1991).

Recent history, however, has shown that, when the economy is hit by large shocks, the fiscal rules may become pro-cyclical and offset the direction of monetary policy (Bianchi and Melosi, 2019, Corsetti et al., 2019, Bartsch et al., 2020). Moreover, there are situations in which interest rate policy loses its effectiveness while fiscal policy is a more powerful stabilisation tool and therefore should be used forcefully. This is the case when the policy rate is close to the effective zero lower bound or when the economy is hit by a shock that breaks down the flow of payments between sectors, as in the lockdown related to the Covid crisis (Woodford, 2020). These considerations have recently motivated policy makers to advocate monetary-fiscal policy coordination (Draghi, 2014, Lagarde, 2020, Schnabel, 2021), while an active discussion is ongoing in Europe about reviewing the fiscal framework.

Even independently of this normative discussion on ‘what should be done’, the issue of monetary-fiscal interaction has assumed an increasing importance as a consequence of the policies that central banks have conducted in the last 15 years which, via quantitative easing (QE) and forward guidance, have targeted long term interest rates. Although it is always the case that monetary and fiscal policies interact, via the general government budget constraint, in affecting the price level, the nature of this interaction is more obvious when public debt is large and the central bank has a large balance sheet.

This paper provides a tentative study of the monetary-fiscal interaction in the Euro Area, through the lens of the aggregate government budget constraint.[1] We ask a positive rather than a normative question and suggest an empirical framework to study the adjustment of fiscal variables, returns and inflation to unexpected monetary policy changes.

Our framework is inspired by Hall and Sargent (1997) and Cochrane (2019, 2020a). Common to their approach is to start from the general government intertemporal budget constraint as an equilibrium identity linking the market value of the debt to future discounted primary surpluses. Since this identity involves bond returns, inflation and fiscal variables, it can be used to learn about the fiscal-monetary adjustment dynamics in an otherwise unrestricted empirical model. While Hall and Sargent (1997) have used the budget constraint condition to propose an accounting exercise aimed at understanding contributions to the US government debt dynamics in the post World War II period, Cochrane (2019) has employed it to study how different components of the constraint adjust to different shocks for the US. We follow this second approach but extend it to apply it to the peculiarities of the monetary union.

As in Cochrane (2019), we use the budget constraint to derive an expression for

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[1] Key references for this type of analysis are, among others, Sims (2013), Leeper and Leith (2016), Reis (2019), Cochrane (2020b). For the Euro Area, see Sims (1999, 2012), Leeper (2017), and Jarociński and Maćkowiak (2018).

unexpected inflation as a function of the changes to the present value of primary surpluses, future real returns, and output growth rate. We then employ the linearised version of the intertemporal budget constraint in conjunction with a Vector Autoregressive (VAR) model. This set-up allows us to study the adjustment to different forms of monetary policy – standard short-term interest rate policy or policies aimed at compressing interest rate spreads. The budget identity is then exploited to obtain estimates of the conditional contributions of its different terms at the business cycle frequency, and in the long-term. The VAR's impulse response functions, on the other hand, provide a visualisation of dynamics at business cycle frequency.

Since the Euro Area is not a unitary system as the US, where there is a single monetary authority and a federal yield curve, we need to extend the framework to the case of a single central bank and multiple fiscal authorities. In the federal case, inflation is determined jointly by fiscal and monetary, possibly under different regimes (as in Leeper, 1991). In the extreme case, the Euro Area can be seen as a set of fiscal authorities independently balancing their budget constraints, by taking the inflation path as given.[2] A more nuanced view is the one in which inflation is determined by the aggregate fiscal and monetary stance, and the aggregate fiscal stance is the sum of the fiscal positions of individual states that may or may not balance their budget independently, and take inflation as given.

Our baseline specification, incorporates this view, that encompass also the case of countries independently balancing their budget. In particular, we adopt this perspective in a model that includes only the four largest countries of the Euro Area: Germany, France, Italy and Spain.[3] While in the benchmark case, we only consider aggregate

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[2] While the national inflations can deviate due to asymmetry shocks, in the medium- and long-run they are tied to the path set by the central bank.

[3] The setting could accommodate the modelling of explicit default. This would feature as a specific reduction in the nominal quantity of debt between periods for a given country. A partial default would instead appear as a low return. We abstract from the case of default that is not empirically relevant for the countries and sample considered.

inflation, we also consider a specification in which national inflations can have differential dynamics. A contribution of the paper is the construction of a new quarterly fiscal dataset of market value of government debts, for the four main Euro Area economies covering the period 1991-2019. The start of the sample marks the German reunification and, shortly thereafter, the signing of the Maastricht treaty in 1992.

As a word of caution, we should stress that the empirical analysis is very challenging, and hence our empirical results provisional. Indeed, in studying the joint monetary-fiscal dynamics in the Euro Area we need to deal with at list three major challenges.

First, it is difficult to identify 'conventional' and 'unconventional' monetary policy shocks, in a time period during which the policy framework in the Euro Area has been constantly evolving in response to a sequence of large macroeconomic events. We deal with this issue by adopting the narrative sign restrictions proposed by Antolin-Diaz and Rubio-Ramirez (2018), and support our identification with a handful of clear policy events.

Second, we need to take implicitly or explicitly a view on how country dynamics aggregate up to the Euro Area dynamics across fiscal and macroeconomic variables. Our formulation of the intertemporal EA budget constraint is an attempt at this. It allows for rich adjustment patterns, yet its interpretation is not univocal.

Third, the study of the long-run adjustment involves choices on the steady state and trend. Such assumptions are always difficult to make, and the long-run is an ill-defined concept. In a monetary union that sees itself in transition towards a closer political union, and over a very short data sample, those concepts are particularly difficult to define.

Notwithstanding these caveats, some results appear to be insightful. They point to an interesting difference in the adjustment to a short term interest rate shock (conventional) and a shock compressing the maturity spread (unconventional). In both cases, monetary policy transmission happens via the decline of the real discount rate, but more strongly so in the second case, partly due to the maturity structure of debt.

In the conventional case, fiscal policy responds to the easing by leaning in the same direction, and by a decline in the primary surplus. In the long-run, the increase in public debt is mostly absorbed by an increase in inflation, while the contribution of nominal returns on the debt is negligible. Conversely, in response to an unconventional shock compressing the term spread, the primary surplus' change is not significant – fiscal policy is nearly neutral – and the small effect on long term inflation is almost entirely explained by the dynamics of nominal returns. Interestingly, the policy effects on real returns are larger than in the conventional case, with a strong decline of the real discount rate mainly via the decline of nominal returns. This pattern of responses is common, albeit with minor differences, to the four countries we consider, for the aggregate results and for the model with country level inflation. Indeed, national inflations show very similar conditional dynamics. In a final exercise, we consider a quasi-fiscal shock that we label 'convertibility' shock, which is defined by an opening or a compression of the periphery (Italian and Spanish) sovereign spread relative to Germany. This is to tease out the effects of shocks to premia, over and beyond the effects of shock to the artificial common yield curve, that can be thought of as the OIS rates. In this case we find that the fiscal response is muted in all countries and inflation adjustment is mostly explained by returns' dynamics.

At a high level, these results suggest that the claim that fiscal policy has been offsetting the effect of monetary policy is only true conditionally on non standard monetary policy. Indeed, we cannot rule out the conclusion that the small effect on GDP in response to these policies is explained by the concomitant passive role of fiscal policy.

The paper is organised as follows. In Section, 2 we discuss different ways of understanding how the budget constraint of the general government can be represented in a monetary union. In Section 3, we discuss the construction of the dataset, while, in Section 4 we outline the econometric framework and the identification strategy. Empirical results are reported in Section 5. The last section concludes.

2 A Fiscal-Monetary Framework for Inflation

In discussing monetary-fiscal interactions, the literature has generally focussed on the case of the US and modelled them as the dynamic interaction between one single monetary authority and one single fiscal authority, be them national or federal (see Cochrane, 2019). In this section, we provide a broad discussion on how the framework can be extended to the case of a monetary union with multiple fiscal authorities and a common central bank.

2.1 Flow and Intertemporal Identities

The aggregate budget constraint and its implications for the aggregate inflation dynamics are at the core of our analysis. Conceptually, it is interesting to distinguish between three cases: a federation where each country faces its own budget constraint and a common inflation rate, a more realistic case in which inflation is common but countries do not need to observe the budget constraint because fiscal transfers are possible, and a full federation with common debt issuance and common inflation.

- **Fiscal Federation**. In the case of a perfect federation, as in the US, there is a single monetary policy, a common inflation and a federal issuance of debt. Hence bonds live on a common yield curve and there is a single aggregate maturity structure. Only the aggregate variables matter and not their state level counterpart (debt is only defined at federal level). As it would be in the case of a single country, the federal government debt flow identity is[4]

$$\rho v_{t+1} = v_t + r_{t+1} - \pi_{t+1} - g_{t+1} - s_{t+1} \ . \tag{1}$$

The log debt to GDP ratio at the end of period $t+1$, v_{t+1}, is equal to its value at the end of the previous period t, v_t accrued by the log nominal return on the portfolio of government bonds r_{t+1} and balanced by (federal nation-wide) inflation π_{t+1} and log output growth g_{t+1}, and less the (scaled) real primary surplus to GDP ratio s_{t+1}. In the equation, ρ is a linearisation constant that depends on the steady state growth rate and returns for the country, i.e. $\rho \equiv e^{g-r}$.

Iterating this equation forward, we obtain a present value identity

$$v_t = \sum_{j=1}^{\infty} \rho^{j-1} g_{t+j} + \sum_{j=1}^{\infty} \rho^{j-1} s_{t+j} - \sum_{j=1}^{\infty} \rho^{j-1} \left(r_{t+j} - \pi_{t+j} \right) \ , \tag{2}$$

that shows that the log value of government debt, in ratio to GDP, is the present value of future surplus to GDP ratios, discounted at the ex-post real return, and adjusted for growth. Taking time $t+1$ innovations $\Delta\mathbb{E}_{t+1} = \mathbb{E}_{t+1} - \mathbb{E}_t$ and rearranging, we have an unexpected inflation identity,

$$\begin{aligned} \Delta\mathbb{E}_{t+1} \left(\pi_{t+1} - r_{t+1} \right) = & - \sum_{j=0}^{\infty} \rho^{j} \Delta\mathbb{E}_{t+1} \left(s_{t+1+j} + g_{t+1+j} \right) \\ & + \sum_{j=1}^{\infty} \rho^{j} \Delta\mathbb{E}_{t+1} \left(r_{t+1+j} - \pi_{t+1+j} \right) \ . \end{aligned} \tag{3}$$

This is the case discussed in Cochrane (2019).

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[4] Following Hall and Sargent (1997, 2011), we explicitly recognise that governments issue debt at different maturities. $r_t = \log(1 + R_t)$ therefore captures all sources of payments to debt holders: explicit ones, in the form of coupon payments and principal repayments, and implicit ones in the form of capital gains from the diminished term to maturity of the debt and interest rate changes on the existing debt.

- **A monetary union with balanced budget rules**. Now let's compare this to the case in which several countries share a common monetary policy but balance their own budget constraint under stringent fiscal rules, by taking the aggregate inflation as given. This can be seen as the institutional setting formalised by the Maastricht Treaty. In fact, while inflation could adjust to make the budget constraint hold, it would not be possible for one single inflation rate to move to solve all of them, lacking explicit coordination.[5] From this prospective, the Euro Area is not different from a set of countries having to borrow in a foreign currency and hence having to adjust real surpluses to avoid defaults.

  Let's move in steps. First, for each country and independently, a flow budget constraint holds. The flow budget constraint can be linearised as

  $$\rho_i v_{i,t+1} = v_{i,t} + r_{i,t+1} - \pi_{i,t+1} - g_{i,t+1} - s_{i,t+1} \qquad \forall i \ . \tag{4}$$

  The flow constraints is, country by country, of the form of Eq. (1), but variables are country specific and ρ_i depends on the country-specific steady state growth rate and returns.

  A common aggregate debt flow identity can be obtained by re-summing over the countries' flow identities weighting them by their output share in the monetary union output $\psi_i \equiv Y_i/Y = V_i/V$

  $$\rho \sum_{i=1}^{n} \psi_i v_{i,t+1} = \sum_{i=1}^{n} \psi_i \left(v_{i,t} + r_{i,t+1}\right) - \pi_{t+1} - g_{t+1} - \sum_{i=1}^{n} \psi_i s_{i,t+1} \ , \tag{5}$$

  where $\pi_t = \sum_{i=1}^{n} \psi_i \pi_{i,t}$ is the currency area wide inflation rate, and we assume

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[5] While in the short-run the inflation rate in each country can deviate from the common path, in the medium run it is determined by the common monetary policy. We use this assumption to substitute the country specific inflation $\pi_{i,t}$ with the common inflation rate π_t.

that $\rho_i \equiv \rho \, \forall i$. This is consistent with assuming that all countries have the same growth rate and returns at the steady state. As done in the case of a federation, it is now possible to obtain an expression for unexpected inflation

$$\begin{aligned}\Delta\mathbb{E}_{t+1}\left(\pi_{t+1}-\sum_{i=1}^{n}\psi_i r_{i,t+1}\right) = &-\sum_{j=0}^{\infty}\rho^j\Delta\mathbb{E}_{t+1}\left(\sum_{i=1}^{n}\psi_i s_{i,t+1+j}+g_{t+1+j}\right)\\ &+\sum_{j=1}^{\infty}\rho^j\Delta\mathbb{E}_{t+1}\left(\sum_{i=1}^{n}\psi_i r_{i,t+1+j}-\pi_{t+1+j}\right) \ . \end{aligned} \tag{6}$$

It is important to stress again that, while inflation rates can and do deviate at country level from the common inflation rate, the fact that the central bank targets average inflation and that country fiscal policy are self-balancing implies that the average inflation rate can be seen as a constraint to the budget determination of each country. It is also important to notice that by assuming that the flow budget constraint (4) holds for each country, the identity (5) can be seen as redundant.

- **A monetary union with transfers**. How would the framework described above change if the flow budget constraint (4) didn't hold country by country, but there could be fiscal transfers? Also how would it change if fiscal authorities did not take inflation as given and externally determine it in balancing their budgets? This would be a case in which each country can emit debt and hence faces different market rates (and returns) but there are potential fiscal transfers across countries. Without requiring the flow budget constraint to hold country by country, it is possible to obtain an expression of the same form of Eq. (6)[6]

$$\Delta \mathbb{E}_{t+1}\left(\pi_{t+1}-\sum_{i=1}^{n}\psi_i r_{i,t+1}\right) = -\sum_{j=0}^{\infty}\rho^j \Delta \mathbb{E}_{t+1}\left(\sum_{i=1}^{n}\psi_i s_{i,t+1+j}+g_{t+1+j}\right) + \sum_{j=1}^{\infty}\rho^j \Delta \mathbb{E}_{t+1}\left(\sum_{i=1}^{n}\psi_i r_{i,t+1+j}-\pi_{t+1+j}\right) . \quad (7)$$

In the empirical analysis we will focus on this specification since it is the one that more realistically represents the Euro Area.

It is worth stressing that in all the three cases discussed, it is possible to obtain an identity in terms of only aggregate quantities at the level of the monetary union (Eq. 3, 6, 7). While these aggregate identities are always satisfied, their underlying adjustment dynamics may differ whether inflation is purely determined by the monetary authority and taken as given by the fiscal authorities, and whether there are fiscal transfers or not. Let us stress that, although we focus on the decomposition in Eq. (7), we remain agnostic on the specific institutional framework.

2.2 Some considerations on spreads and the yield curve

To gain some additional intuition on how the Euro Area differs from the case of a perfect federation, it is useful to derive a different formulation of the inflation decomposition in Eq. (7). The key observation is that each country is issuing securities with a different risk and maturity profile, and this implies that the return premia across countries impact the flow budget and hence can impact inflation dynamics.

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[6] Here all the variables, with the exception of surpluses, are defined as log ratios of the variables of interest to the total monetary union GDP.

First, we rewrite the aggregate flow budget constraint as

$$\rho v_{t+1} = v_t + \overline{r}_{t+1} + \sum_{i=1}^{n} \psi_i prem_{i,t+1} - \pi_{t+1} - g_{t+1} - s_{t+1} \ . \tag{8}$$

where $\overline{r}_{t+1} \equiv \frac{1}{n}\sum_{i=1}^{n} r_{i,t+1}$ is the average rate across countries and can be seen as a base rate – connected to a synthetic common yield curve –, while the return premia are defined as $prem_{i,t+1} \equiv (R_{i,t+1} - \overline{R}_{t+1})/\overline{R}_{t+1}$. Then, we proceed as before to obtain

$$\begin{aligned}\Delta\mathbb{E}_{t+1}\left(\pi_{t+1} - \overline{r}_{t+1} + \sum_{i=1}^{n} \psi_i prem_{i,t+1}\right) &= -\sum_{j=0}^{\infty} \rho^j \Delta\mathbb{E}_{t+1}\left(s_{t+1+j} - g_{t+1+j}\right) \\ &+ \sum_{j=1}^{\infty} \rho^j \Delta\mathbb{E}_{t+1}\left(\overline{r}_{t+1+j} + \sum_{i=1}^{n} \psi_i prem_{i,t+1+j} - \pi_{t+1+j}\right) \ . \end{aligned} \tag{9}$$

We can then define an effective rate of return on the aggregate governments' debt portfolio as the rate that balance the total debts as

$$\widehat{r}_{t+1} \equiv \overline{r}_{t+1} + \sum_{i=1}^{n} \psi_i prem_{i,t+1} \ . \tag{10}$$

Substituting in Eq. (8), the flow budget constraint has the same shape of the federal one, above. However, both risk and maturity premia have now country idiosyncratic dynamics. The crucial difference between a federation and a monetary union is the lack of a common yield curve and hence the presence of country spread dynamics. Indeed, this is of particular importance in the EA where the ECB needs to have an eye on both the position of the yield curve and the average financial conditions that crucially depends on the country-level premia.

Monetary policy affects different terms of real returns: (i) the expected path of inflation; (ii) the expected path of the short term interest rates or the average returns on one period bonds, that could be thought of as the OIS curve; (iii) the term premia over the average returns; and (iv) the country-specific premia, that blend idiosyncratic risks and maturity structure. Different types of policies – short term interest rate changes, spread compression via quantitative easing, forward guidance or policies aimed at decreasing sovereign premia – affect these components in differential ways.

2.3 Adjustment Mechanisms

In our empirical discussion, Eq. (7) provides us with a decomposition of how adjustments to inflation, relate to surpluses, returns and growth rates in the short and long run.

In order to better understand the meaning of the unexpected inflation decomposition, it is worth to observe that an unexpected increase in inflation has to correspond to a decline in the present value of surpluses, coming either from a decline in surplus to GDP ratios, or a decline in GDP growth; or a rise in the discount rates due to a decline in nominal long-term bond prices. These adjustments in the aggregate can happen as combination of symmetric or asymmetric changes at country level.

Importantly, several causal mechanisms of adjustment can be possible empirically, given the institutional framework, the maturity structure of the debts issued and country-level dynamics. While the identity is silent about the causal mechanisms, we will be looking at causal effects of monetary policy by identifying policy shocks in a VAR model. This will allow for interpretability.

The discussion on the different budget constraints shows the complexity of the interaction between country-level primary surpluses, returns and inflation in shaping the complex interaction between monetary and fiscal policy in a monetary union. The decomposition in Eq. (9), provides a different angle to our discussion, highlighting the potential heterogeneous dynamics of returns at country level. Such dynamics – that can involve flight to safety events – has been at the forefront of the sovereign debt crisis in 2011, and featured very high in the policy concerns of the ECB during the

COVID pandemic. We will explore these type of events in studying the consequences of a 'convertibility' shock that compresses (or opens up) country spread.

In the next section we will describe the empirical model that we use to estimate the responses to monetary policy shocks by the variables entering the budget identity. Equation (7) can then be used to decompose the inflation adjustment at different horizons.

3 Market Values of Debts and Total Returns

We construct a new quarterly fiscal dataset for the four main Euro Area economies covering the period 1991-2019. As mentioned in the introduction, we are interested in collecting information on the market value of government debt and on total return that accounts for capital gains on outstanding debt stemming from the diminished term to maturity of the debt or interest rate changes. This measure makes the debt dynamic identity in (2) hold with equality.[7] We do not net out the holdings of Euro Area government bonds at the ECB. In principle, one should exclude them from our measure of the market value of the debt for each country. However, these purchases are matched with interest-paying deposits on the liability side of the central bank's balance sheet, which should also form part of the measure of public debt, and therefore the purchases of debt by the ECB just substitute one form of government liability for another (Sims, 2013; Cochrane, 2014; Reis, 2019).[8]

We derive the data for the market value of debt by aggregating information from various sources. The IMF International Financial Statistics provide data at quarterly

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[7] Notice that in an environment in which the government only issues one-period debt, the two concepts coincide.

[8] While the total amount of government liabilities does not change, its maturity does, and so does the flow of seignorage payments from the central bank to the treasury. A more detailed treatment of this issue will become quantitatively important in coming years, as the ECB has increased its purchases of Euro Area government debt securities as a consequence of the COVID-19 pandemic.

frequency from 1999. Eurostat, in turn, provides annual data starting in 1995 from the consolidated Financial Accounts. Historical series, available at annual and quarterly frequencies from national sources, are used to reconstruct these back to 1991, and mixed-frequency methods are used whenever necessary to temporally disaggregate the annual data using closely related quarterly series. Government primary surpluses are constructed in a similar manner. Both data are then seasonally adjusted using the Census X-13 program. Full details are given in B.

With data for debt and surpluses at hand, we back out the return on the government debt portfolio from the debt dynamic identity. This is the same approach followed for the United States by Eisner and Pieper (1984), Eisner (1986), and Bohn (1992). The advantage of this approach is that it makes the budget constraint hold exactly. The disadvantage is that any measurement error in the calculation of the surplus, or any discrepancy in definition between the debt and the deficit will contaminate the return series. This concern is important in the Euro Area, where a number of very large fiscal events, such as government bailouts to financial institutions after the 2008 crisis, or the bailouts associated with the European Sovereign Debt Crisis are accounted differently across debt and deficits in a number of countries. These outlier movements in fiscal variables can be thought of as one-off large events that come from a different data generating process than the one governing the usual dynamics of government deficits, but could have an out-sized effect on VAR estimates. For this reason, we systematically remove them from the series while maintaining consistency of the budget constraint equation.[9] We complete the database with series for Euro Area-wide GDP and price index, as well as the 3-month interest rate and the yields on 10-year government bonds for the four countries. Finally, to capture the low-frequency decline in inflation present in the data, we include a measure of long-term inflation expectations, defined as the

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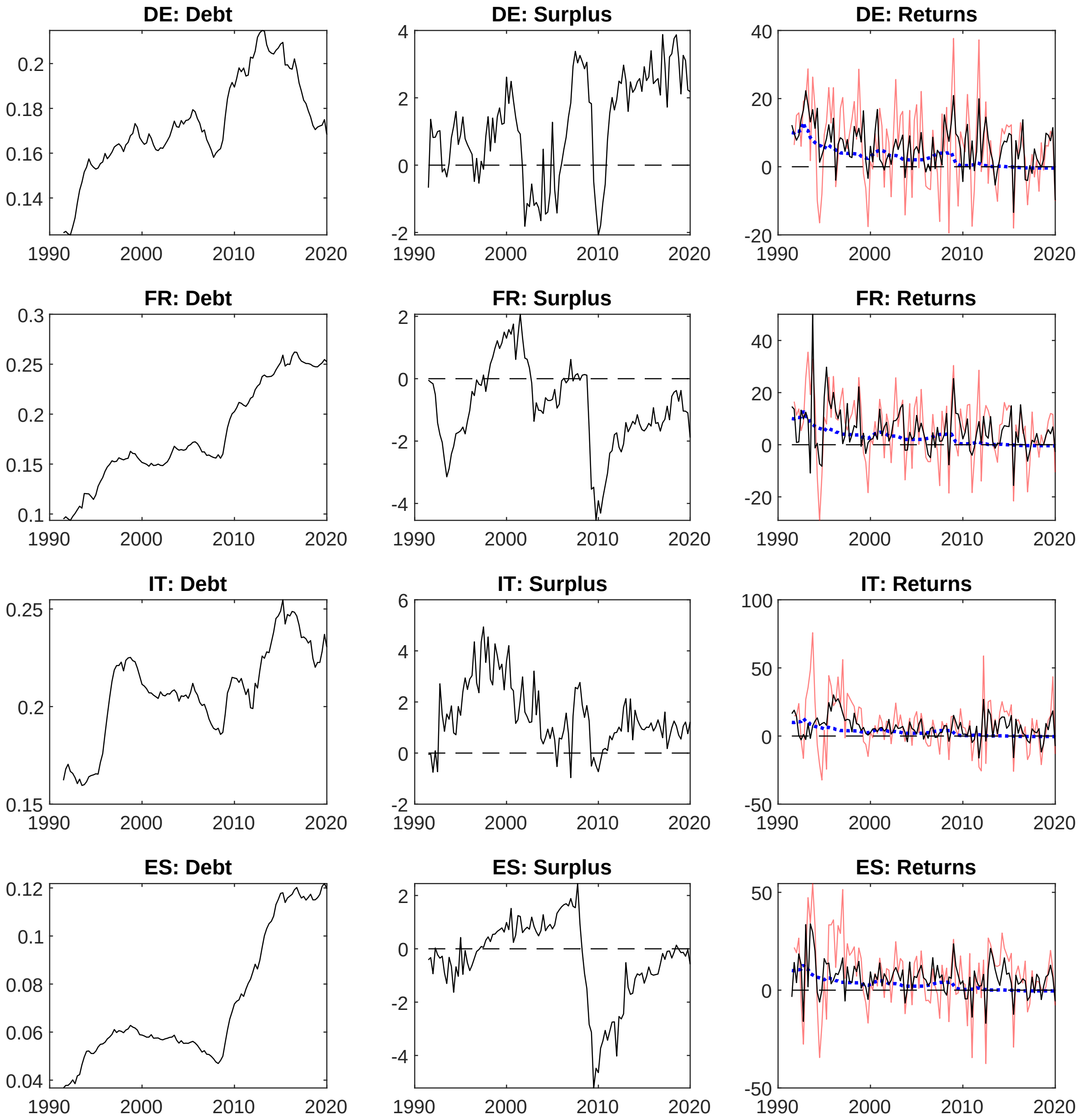
[9] Full details are given in Appendix B.

mean expected inflation rate over the next 10 years from the survey of professional forecasters run by Consensus Economics.

Figure 1 plots the key fiscal variables for the four largest Euro Area economies in each row. The first column plots $V_{i,t}/P_tY_t$, the ratio of the value of debt to Euro Area GDP. The second column plots 100 times $SPY_{i,t}$, the ratio of the primary (excluding interest payments) surplus to euro-area GDP. The third column plots (i) in black, the nominal return on the government debt portfolio, r^n, (ii), in dotted blue, the 3-month interest rate, common to all countries, and (iii) in light red, the one-period holding return on a 10-year bond. All variables are expressed at annual rates.

Three observations are in order. First, the debt is highly persistent over the sample, trending strongly upwards in France and Spain and somewhat less so in Germany and Italy. Second, and relatedly, there is substantial heterogeneity in the surplus processes of the four economies. Germany and Italy have run primary surpluses on average over the sample, whereas France and Spain, which were on balance before the crisis, struggled to achieve a primary surplus in the post-crisis period. On aggregate, the total Euro Area surplus is highly cyclical and close to balanced over the sample. The third observation concerns the returns on the government's debt portfolios. These co-move strongly with the returns on 10-year zero-coupon bonds (light red), although they are less volatile. The returns on the government debt portfolio are reasonably well approximated by a linear combination of the short-term interest rate (dotted blue line) and the long-term bond return.

Figure 1: Fiscal Variables for Main Euro Area Countries



Note: The figure plots the key fiscal variables for the four largest Euro Area economies in each row. The first column plots $V_{i,t}/P_tY_t$, the ratio of the value of debt of each country to the Euro Area GDP. The second column plots 100 times $SPY_{i,t}$, the ratio of the primary (excluding interest payments) surpluses to GDP. The third column plots (i) in black, the return on the government debt portfolio, r^n, (ii) in dotted blue, the 3-month interest rate, common to all countries, and (iii) in light red, the one-period holding return on a 10-year bond. All variables are expressed at annual rates.

4 Econometric Framework

We model the variables in our dataset as evolving according to a structural vector autoregression (SVAR), written compactly

$$\mathbf{y}_t'\mathbf{A}_0 = \mathbf{x}_t'\mathbf{A}_+ + \boldsymbol{\varepsilon}_t' \text{ for } 1 \leq t \leq T, \tag{11}$$

with $\mathbf{A}_+' = \begin{bmatrix} \mathbf{A}_1' & \cdots & \mathbf{A}_p' & \mathbf{d}' \end{bmatrix}$, $\mathbf{x}_t' = \begin{bmatrix} \mathbf{y}_{t-1}', \ldots, \mathbf{y}_{t-p}', 1 \end{bmatrix}$, where $\mathbf{y}_t$ is an $n \times 1$ vector of observables, $\boldsymbol{\varepsilon}_t$ is an $n \times 1$ vector of structural shocks, $\mathbf{A}_\ell$ is an $n \times n$ matrix of parameters for $0 \leq \ell \leq p$ with $\mathbf{A}_0$ invertible, $\mathbf{d}$ is an $1 \times n$ vector of parameters, p is the lag length, and T is the sample size. The vector of shocks $\boldsymbol{\varepsilon}_t$, conditional on past information and the initial conditions $\mathbf{y}_0, ..., \mathbf{y}_{1-p}$, is distributed $\mathcal{N}\left(\mathbf{0}_{n\times 1}, \mathbf{I}_n\right)$, where $\mathbf{0}_{n\times 1}$ is an $n \times 1$ matrix of zeros and $\mathbf{I}_n$ is an $n \times n$ identity matrix. The reduced-form representation implied by Equation (11) is

$$\mathbf{y}_t' = \mathbf{x}_t'\mathbf{B} + \mathbf{u}_t' \text{ for } 1 \leq t \leq T, \tag{12}$$

where $\mathbf{B} = \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t' = \boldsymbol{\varepsilon}_t'\mathbf{A}_0^{-1}$, and $\mathbb{E}\left[\mathbf{u}_t\mathbf{u}_t'\right] = \boldsymbol{\Sigma} = \left(\mathbf{A}_0\mathbf{A}_0'\right)^{-1}$. The matrices $\mathbf{B}$ and $\boldsymbol{\Sigma}$ are the reduced-form parameters, while $\mathbf{A}_0$ and $\mathbf{A}_+$ are the structural parameters. Similarly, $\mathbf{u}_t'$ are the reduced-form innovations. While the shocks are orthogonal and have an economic interpretation, the innovations may be correlated and do not have an interpretation.

As it is well known, the model defined in Equation (11) has an identification problem. As described in Lippi and Reichlin (1994), one can reparameterise this model in terms of $\mathbf{B}$ and $\boldsymbol{\Sigma}$ together with an $n \times n$ orthogonal rotation matrix $\mathbf{Q}$, such that for a given $\mathbf{B}$ and $\boldsymbol{\Sigma}$, a choice of $\mathbf{Q}$ implies a particular, observationally equivalent choice of structural parameters. To solve the identification problem, one often imposes restrictions on either the structural parameters or some function–such as the impulse response functions (IRFs)–thereof, pinning down a particular **Q** (point identification) or narrowing down a set of **Q**'s (set identification).

4.1 Bayesian priors

Our sample covers the period 1991Q2 to 2019Q4. Such a short sample, together with the large number of variables included in the model, poses challenges for the estimation of the model. Most importantly, as seen in Figure 1, the debt-to-GDP ratios are highly persistent and appear to trend up in the sample, whereas both the provisions of Maastricht treaty and the assumptions underlying the derivation of the log-linear budget constraints require them to be stationary. VARs estimated with classical methods or uninformative priors would struggle to produce sensible estimates with highly persistent debt ratios over short samples. We solve this issue by imposing a dogmatic prior over the steady state of the system.

The steady state prior is consistent with the debt-to-Euro-Area-GDP ratios of each of the countries being equal to 60% times the share of each country, and the primary surpluses being zero in the long run. We also impose that the steady state inflation rate is equal to 1.9%, 'below but close to 2%' as specified by the ECB's inflation objective. For real GDP growth, we fix the steady state at 1.5%, close to the sample average. Consistent with our choice for the steady state surplus, we fix the steady-state returns on the government debt portfolio at $r^{\star} = g^{\star} + \bar{\pi}^{\star} = 3.4\%$. Finally, the short term real interest rate is assumed to be 1% in steady state, the spread between the long- and short-term interest rates to be 100 basis points, the sovereign spread to be 50 basis points for France, and 100 basis points for Italy and Spain.

We implement this dogmatic prior by subtracting the steady state values from each of the series and running the VAR in deviations from the steady state without a constant term.[10] Moreover, we apply a standard Normal-Inverse Wishart prior on the reduced form coefficients $\mathbf{B}$ and $\mathbf{\Sigma}$. This prior is centred around autoregressive coefficients being 0 for real GDP growth, inflation minus inflation expectations, returns, and 0.5 for more persistent variables – i.e. short-term interest rate, slope of the yield curve, spreads, surpluses, and debt values. It is instead centred around an autoregressive coefficient equal to 1 for inflation expectation. The tightness of the prior increases with the lag length and is governed by a parameter λ which we set to 0.1.

To ensure the stationary of the system, following Cogley and Sargent (2001), we discard any draw of the parameters that implies any root greater than 0.99. This procedure truncates and renormalises the prior to rule out explosive debt-to-GDP paths.

4.2 Identification Strategy

We perform the VAR analysis in response to three identified shocks. The first shock is a conventional monetary policy (MP) shock, intended to capture deviations of the short-term interest rate from the systematic reaction of the central bank to economic developments. The second, is an unconventional monetary policy (UMP) shock, which captures central bank forward guidance and quantitative easing which affect longer-term interest rates.

The third shock, which we call a 'convertibility' shock, can be seen as a shock that either opens up or compresses the core-periphery spread. This type of dynamics is associated to 'flight to safety' events when capitals flow from the periphery to the core countries, putting upward pressure on bond yields of Italy and Spain especially, and downward pressure on the bond yields of Germany. Following a policy announcement – as, for example, the Outright Monetary Transactions program of the ECB – financial

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[10] Appendix B provides a detailed description of the dataset and of the transformation adopted. In our model, all the variables enters in annualised percentage deviation from the steady state, for sake of interpretability of the IRFs.

markets stress subsides and these movements can be reversed. A possible way to interpret such shocks is to think of them as markets pricing the increased risk of peripheral bonds towards safer German bonds, when a negative shock threatens convertibility in the Euro Area. This shock is not strictly speaking a monetary policy shock, but our goal is to capture the pattern of events surrounding the announcement of the OMT, which aimed to stabilise self-fulfilling fears of a breakup of the Euro Area in the summer of 2012.

We identify the shocks in the model using a combination of sign restrictions, as in Uhlig (2005), and the recently proposed narrative sign restrictions of Antolin-Diaz and Rubio-Ramirez (2018). We discuss both of these in turn. With respect to traditional sign restrictions, we constrain an expansionary conventional MP shock to have a negative impact on the short and long term interest rates, a positive impact on output, and a positive impact on inflation and inflation expectation for the first three quarters (inflation moving by a larger amount). We separately identify the MP and UMP shocks based on their differential impact on the yield curve. The MP shock is assumed to move short term interest rates by a larger amount than long term rates, leading to a steepening of the yield curve. The UMP shock has the opposite effect on the slope. Finally, we identify the (positive) convertibility shock by imposing a negative impact on the sovereign spreads of Italy and Spain and a positive impact on the German long-term yield. As discussed, the latter assumption is intended to capture a 'flight to safety' effect from risky peripheral bonds towards safer German bonds when a negative shock threatens convertibility in the Euro Area. Importantly, all three identified shocks are assumed to be neutral in the long-run for real output.

We complement the restrictions on impulse responses with narrative sign restrictions, following Antolin-Diaz and Rubio-Ramirez (2018). Narrative sign restrictions constrain the structural shocks and/or the historical decomposition around key historical events, ensuring that they agree with a narrative account of these episodes. For instance, if based on historical accounts and qualitative sources there is agreement that a contractionary monetary policy shock occurred on a particular date, structural parameters that produce shocks consistent with policy being eased during that period would be ruled out. Antolin-Diaz and Rubio-Ramirez (2018) show that this class of restrictions leads to much tighter inference than traditional sign restrictions, which often fail to reject models with implausible implications for elasticities, shock realisations and historical decompositions.[11] Specifically, we introduce the following narrative sign restrictions.

Narrative Sign Restriction 1: Conventional monetary policy shock *A contractionary (negative) conventional monetary policy shock happened on the third quarter of 2008 and the first quarter of 2011. Moreover, it was the single largest contributor to the unexpected movement in the short term interest rate during those two periods.*

Both of these events relate to circumstances in which the ECB increased interest rates on the basis of headline inflation being above target. Observers of ECB policy have argued that both of these events represented policy mistakes, since inflation dynamics was largely explained by oil prices, and the ECB underestimating the severity of the recessions that were already underway during both periods (see Hartmann and Smets (2018) and the discussion contained herein). While for the second of these events the policy rate was raised in April and July of 2011, we place the timing of the shock in the first quarter of 2011 as the ECB had strongly hinted to its intention of increasing the interest rate during the first quarter of the year, and by the time the change occurred, it was widely expected.

Narrative Sign Restriction 2. Unconventional monetary policy shock *An expansionary (positive) unconventional monetary policy shock took place on the first*

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[11] This point has been forcefully argued by Kilian and Murphy (2012), Arias et al. (2016), Ludvigson et al. (2017) and Antolin-Diaz and Rubio-Ramirez (2018).

quarter of 2015. Moreover, it was the single largest contributor to the unexpected movement in the term spread between the German long-term interest rate and the short-term interest rate during that period.

This restriction is motivated by the announcement in January of 2015 of a large Asset Purchase Programme (APP), with average monthly purchases of public and private sector securities of €60 billion. Through the portfolio rebalancing and signalling channels, this put further downward pressure on long-term interest rates and flattened the slope of the yield curve (Cœuré, 2015). While again the programme had been hinted during the previous months, those anticipation effects are confounded with a general decline in growth prospects for the Euro Area at the end of 2014. The announcement itself was much larger than market participants expected, leading us to consider that despite the presence of anticipation effects, an expansionary shock did occur in January 2015.

Narrative Sign Restriction 3. Convertibility shock. *There was a negative convertibility shock in the second quarter of 2012, and a positive one in the third quarter of 2012. Moreover, this shock was the single largest contributor to the unexpected movement in Italian and Spanish sovereign spreads during these periods.*

The negative shock in 2012 Q2 captures the tensions in the European sovereign debt market that led to large increases in sovereign spreads, fuelled by fears of a potential break-up of the Euro Area. The positive shock in 2012 Q3 corresponds to the announcement of the OMT program, after ECB president Mario Draghi declared that the central bank would do ‘whatever it takes’ to preserve the euro.

4.3 VAR Specifications

We identify structural shocks and study the fiscal monetary dynamics in three models: (i) a small VAR in which only Euro Area aggregates are included, (ii) our benchmark specification, i.e. a larger VAR model in which surplus, debt, and return for the four countries enter the VAR individually, (iii) an expanded version of the benchmark VAR model that also includes country-specific inflation. The priors and identification restrictions are the same across the different models.[12] Details of the three models are reported in Appendix B.

5 EA Inflation & Fiscal-Monetary Crosswinds

The empirical framework delivers results on adjustment dynamics to monetary shocks both at business cycle frequency and in the long run. We report the dynamic responses in the form of structural impulse response functions to the identified shocks (Figures 2-6), and then summarise the long-run adjustment employing the unexpected inflation decomposition derived in Section 2 (Tables 1-3).[13]

5.1 Monetary Policy Shocks

We first discuss the effects of a conventional monetary policy easing. For this exercise, we report two sets of results. First, a smaller VAR in which only Euro Area aggregates are included (results are reported in Figure 2). Second, the results from a larger model in which surplus, debt, and return for the four countries enter the VAR individually.

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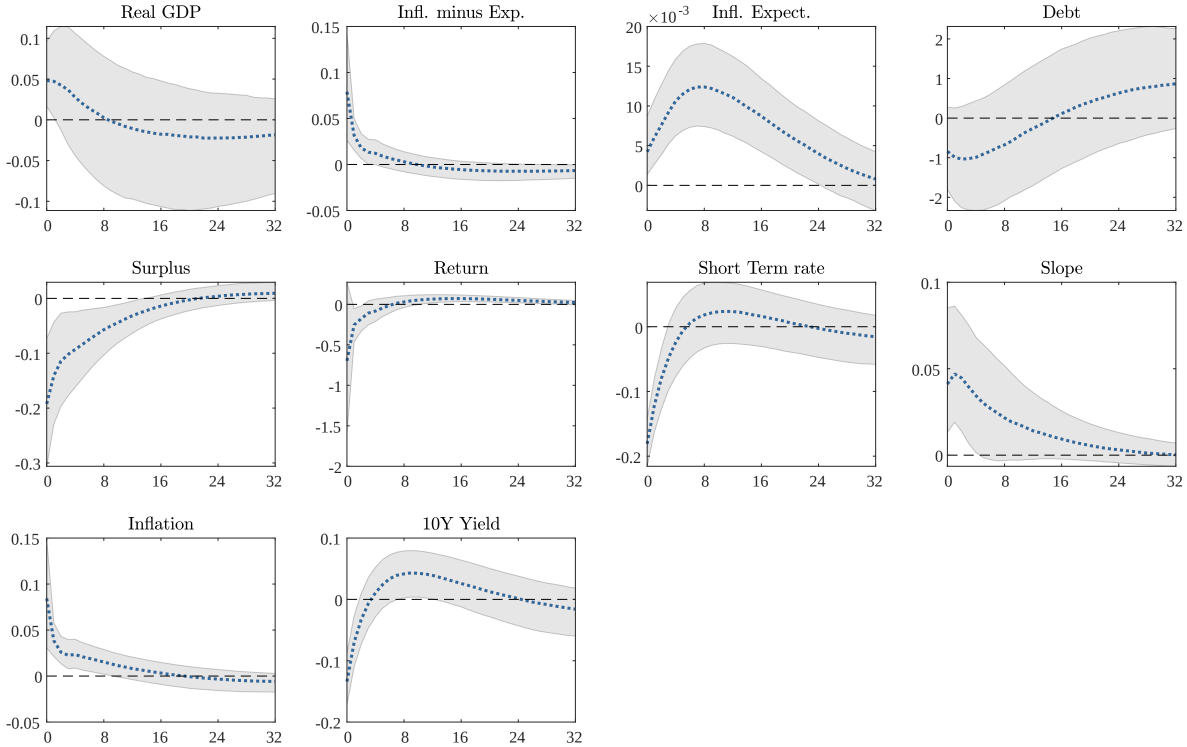
[12] To be consistent with our main specification, the spread between the long- and short-term interest rates in (i) is assumed to be 150 basis points in steady state. In (iii), the monetary policy shocks are assumed to have impacts of the same sign on all national inflation rates.

[13] Additional charts and results are in Appendix C. We follow the convention in the literature and report pointwise medians and 68% High Posterior Density intervals to aid the interpretation of the figures, although the drawbacks of this approach have been highlighted by Inoue and Kilian (2020).

Figure 2: Conventional Monetary Policy Shock

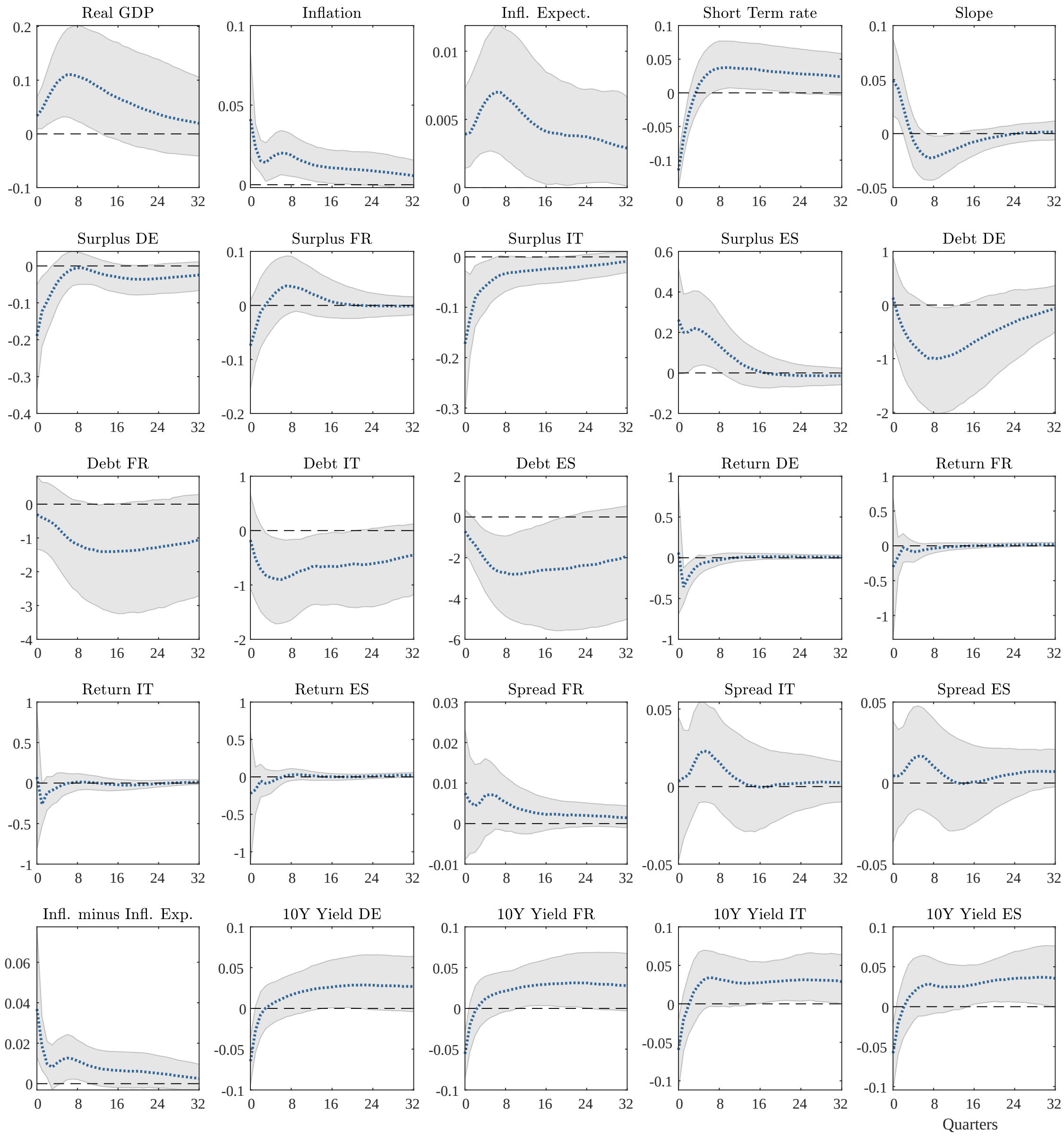


Note: The figure shows impulse response functions to a one standard deviation conventional monetary policy shock (easing) in the Euro Area, using the small VAR with only aggregates. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflation, inflation expectation, short-term rate, slope, return, and yield correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Number of draws: 2002.

These are shown in Figure 3. We will see that the results of both specifications are qualitatively very similar.

The charts show the dynamic responses to a shock inducing a one standard deviation policy easing. In the sample, this represents a small cut in the short term interest rate, of about 10 basis points for the larger VAR, which reverts within a few quarters. There is a hump-shaped impact on GDP in Figure 3, peaking at about 0.1% in the second year, and an immediate impact on inflation and inflation expectations. In line with the

Figure 3: CONVENTIONAL MONETARY POLICY SHOCK



Note: The figure shows impulse response functions to a one standard deviation conventional monetary policy shock (easing) in the Euro Area, using the larger model in which surplus, debt, and return for the four countries enter the VAR individually. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflation, inflation expectation, short-term rate, slope, returns, spreads, and yields correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Number of draws: 762.

transitory nature of the shock, the impact on long-term yields is both small in magnitude and short lived. Focusing on the responses of the fiscal variables, in the aggregate model we observe a significant immediate decline in the surplus-to-GDP ratio. Looking at Figure 3, we can see that this is driven mostly by Germany and Italy, whereas the response of the French surplus ratio is negative but not significant, and the Spanish surplus responds with a positive sign. The value of debt-to-EA-GDP ratio falls for all countries in the first two years, although the aggregate response is not significant.

The response of the return on government debt is ambiguous: recall that the monetary policy shock has a muted impact on long-term yields, which move inversely to returns, and a strong impact on short term interest rates. Finally, we observe that sovereign spreads do not appear to react significantly to the conventional MP shock, indicating a symmetric transmission across the Euro Area. To summarise, we observe evidence of fiscal-monetary coordination to a monetary policy easing: in response to the decline in interest rates, the fiscal authorities allow the surplus-to-EA-GDP ratio to decline. The overall impact of the policy is an increase in output, an increase in inflation, and an insignificant decline in the debt-to-EA-GDP ratio.

Table 1 examines the results through the lens of the budget identity in Eq. (7), repeated here for convenience

$$\begin{aligned}\Delta \mathbb{E}_{t+1}\left(\pi_{t+1}-\sum_{i=1}^{n}\psi_{i,t}r_{i,t+1}\right) = &-\sum_{j=0}^{\infty}\rho^{j}\Delta\mathbb{E}_{t+1}\left(\sum_{i=1}^{n}\psi_{i,t}s_{i,t+1+j}+g_{t+1+j}\right)\\ &+\sum_{j=1}^{\infty}\rho^{j}\Delta\mathbb{E}_{t+1}\left(\sum_{i=1}^{n}\psi_{i,t}r_{i,t+1+j}-\pi_{t+1+j}\right).\end{aligned}$$

The results of the table account for the response of inflation conditional on a monetary policy shock, into the contribution of each of the components of Eq. (7). The table reports the average across individual draws of the posterior for each of the

Table 1: INFLATION DECOMPOSITION – CONVENTIONAL MONETARY POLICY SHOCK

Variable / Country	Germany	France	Italy	Spain	**Total**
L.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$\Delta\mathbb{E}_{t+1}\pi_{t+1}$					0.05
$-\Delta\mathbb{E}_{t+1}\psi_{i,t}r_{i,t+1}$	$-(0.02)$	$-(-0.09)$	$-(0.01)$	$-(-0.03)$	$-(-0.08)$
R.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{\infty}g_{t+j+1}$					0
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{\infty}\psi_{i,t}s_{i,t+1+j}$	$-(-0.46)$	$-(0.14)$	$-(-0.3)$	$-(0.2)$	$-(-0.42)$
$\Delta\mathbb{E}_{t+1}\sum_{j=1}^{\infty}\psi_{i,t}r_{i,t+1+j}$	-0.17	0.13	-0.02	0.16	0.1
$-\Delta\mathbb{E}_{t+1}\sum_{j=1}^{\infty}\pi_{t+1+j}$					$-(0.38)$

Note: The unexpected inflation decomposition follows from the identity in Eq. (7). The first two rows report the left hand side (L.H.S.) of Eq. (7) for each country, and their sum in the last column of the table. These terms are balanced by the right hand side (R.H.S.) of Eq. (7) in the last three rows for each country, and their sum in the last column of the table. Numbers are computed draws by draw, and the means across all draws are reported. Number of draws: 762.

quantities reported. The small initial impact on inflation, of about 5 basis points, is accompanied by a similar magnitude but opposite sign movement (-8 basis points) in the contemporaneous return. On the right hand side of the equation, we see the breakdown into future expected growth, future expected surpluses, and future expected returns and inflation. Recall that the contribution of future growth rates is exactly zero because of the long-run neutrality assumption.

The table provides interesting insight. A one standard deviation easing conventional monetary policy shock corresponds in the long run to a 10 basis point movement in the cumulative future expected nominal returns and a 38 basis point increase in expected inflation. Hence the real discount rate – i.e. $r - \pi$ – declines by minus 28 basis points. This compression of the real rates opens up the space to absorb roughly two thirds of the increase in fiscal deficit, i.e. a drop of 42 basis points in expected surpluses. The reminder of the increase in debts is absorbed by the unexpected inflation and the movement of returns at time t+1. At the country level, Germany and Italy loosen their fiscal stance, leaning towards the monetary easing, while France and Spain maintain an overall more neutral stance. Overall, the increase in inflation, quarter by quarter, is small and mainly happens at the business cycle horizon. To summarise, the monetary policy shock is accompanied by a small but persistent increase in prices, and a decline of the real discount rate. Together they absorb a 42 basis points increase in deficit in the aggregate, that is mainly due to Germany and Italy.

5.2 Unconventional Monetary Policy Shocks

Figures 4 and 5 show the responses to a one standard deviation unconventional monetary policy easing in the Euro Area aggregate and the disaggregated VARs, respectively. In Figure 4, this represents a 20 basis points decline in the long-term average yield, which reverts within two years. The response of the short-term rate is negligible. We observe a positive reaction of output and inflation, and no significant movements in fiscal variables. This happens despite an unambiguous response of the returns on government debt, which maps to an increase in market value of the debt due to the decline in longer-term yields.[14] While the value of the debt increases on impact, the response is not significant beyond the first period. Results are qualitatively similar in the disaggregate system where one standard deviation shock corresponds to a 10 basis points decline in the

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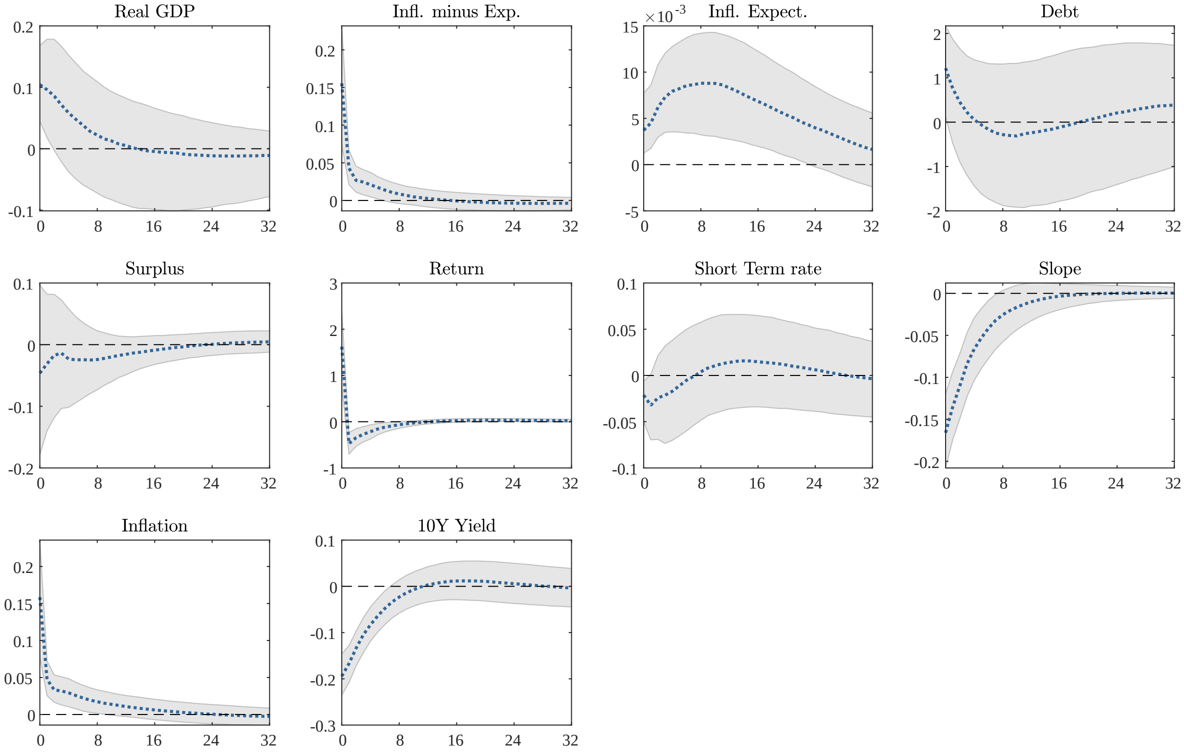
[14] In the disaggregated model we can see that Spain is the exception, with the response of the return not well identified on impact.

long-term average yield (in Figure 5). The effect on output and inflation appears muted and not persistent. Interestingly, in this case, the response of inflation is estimated to be bigger on impact but less persistent than in the case of the conventional MP shock.

Figure 4: Unconventional Monetary Policy Shock



Note: The figure shows impulse response functions to a one standard deviation unconventional monetary policy shock (easing) in the Euro Area, using the small VAR with only aggregates. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflation, inflation expectation, short-term rate, slope, return, and yield correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Number of draws: 2002.

The unexpected inflation decomposition, reported in Table 2, shows that the 10 basis point decline in the long-term rates due to the unconventional monetary policy shocks corresponds to a large adjustment of the nominal returns that jump of 93 basis points in the short run, to contract of 81 basis points in the long-run. Inflation movements are muted with a jump of 9 basis points in the short run and 15 basis points of additional cumulative unexpected inflation in the long-run. Thus, the long-run real discount rate declines of 96 basis points. This points to the strong and persistent effects of unconventional monetary policy on the real rates, one of the key mechanisms through which monetary policy operates. However, differently from the case of conventional monetary policy, the deficit increases by only 14 basis points. This, in turns, explains the large jump of returns in the short run. The small increase in deficit is due to the heterogenous dynamics at country level where Italy and France loosen, while Germany and Spain adjust. Overall, surplus numbers at the country level are small, with the exception of Italy. To sum up, differently from the conventional monetary policy case where the decline in the real rates (and some extra inflation) was matched by fiscal deficit, in the case of unconventional monetary policy the large decline of the discount rate is not associated with a fiscal expansion. The response of inflation is muted, and so is the response of output at business cycle frequency.

5.3 Convertibility Shocks

Finally, we focus on the impact of the convertibility shock in Figure 6. The IRFs plot a positive shock, meaning a shock compressing the core-periphery sovereign spreads. The responses to a one standard deviation shock imply a fall of about 15 basis points in Spanish and Italian sovereign spreads, of about 5 basis points in the French spread, and a small increase in German yields. Despite a large reaction of the returns, the responses of fiscal variables are also not clearly identified. Only for Italy there is an unambiguous increase in the value of the debt in the short-term. As for the surpluses, none of the countries reacts significantly. Interestingly, the reaction of output is positive, although not significant, but we observe a small but significant decline in inflation.

The decomposition, in Table 3, indicates that in the aggregate a convertibility shock

Table 2: INFLATION DECOMPOSITION – UNCONVENTIONAL MONETARY POLICY SHOCK

Variable / Country	Germany	France	Italy	Spain	**Total**
L.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$\Delta\mathbb{E}_{t+1}\pi_{t+1}$					0.09
$-\Delta\mathbb{E}_{t+1}\psi_{i,t}r_{i,t+1}$	$-(0.29)$	$-(0.35)$	$-(0.29)$	$-(-0.01)$	$-(0.93)$
R.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{\infty}g_{t+j+1}$					0
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{\infty}\psi_{i,t}s_{i,t+1+j}$	$-(0.12)$	$-(-0.11)$	$-(-0.21)$	$-(0.06)$	$-(-0.14)$
$\Delta\mathbb{E}_{t+1}\sum_{j=1}^{\infty}\psi_{i,t}r_{i,t+1+j}$	-0.11	-0.4	-0.33	0.03	-0.81
$-\Delta\mathbb{E}_{t+1}\sum_{j=1}^{\infty}\pi_{t+1+j}$					$-(0.15)$

Note: The unexpected inflation decomposition follows from the identity in Eq. (7). The first two rows report the left hand side (L.H.S.) of Eq. (7) for each country, and their sum in the last column of the table. These terms are balanced by the right hand side (R.H.S.) of Eq. (7) in the last three rows for each country, and their sum in the last column of the table. Numbers are computed draws by draw, and the means across all draws are reported. Number of draws: 1125.

corresponds to a decline of the future real discount rate of 38 basis points, due to the movement of nominal returns. This decline is almost entirely absorbed, in the short-run, by a small decrease in inflation (4bps) and a large jump in nominal returns (32bps). Hence, the surpluses barely move in the aggregate (6bps), and also at country level.

To conclude our discussion, let us mention results from a VAR with country-specific inflation, reported in the Appendix C. We include national inflations in our benchmark model to provide evidence on the potential differential adjustment, at business cycle

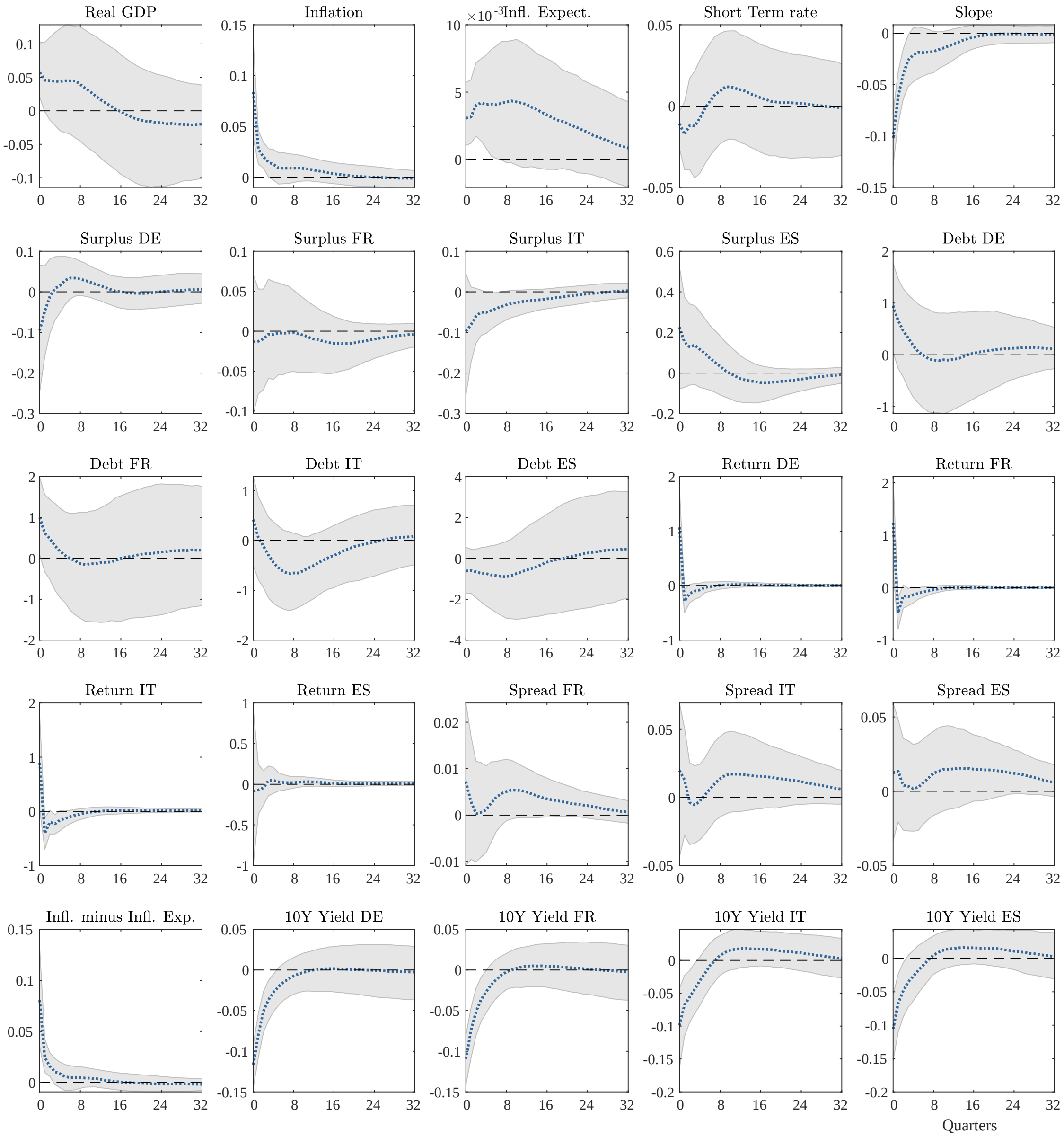
Table 3: INFLATION DECOMPOSITION – CONVERTIBILITY SHOCK

Variable / Country	Germany	France	Italy	Spain	**Total**
L.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$\Delta\mathbb{E}_{t+1}\pi_{t+1}$					-0.04
$-\Delta\mathbb{E}_{t+1}\psi_{i,t}r_{i,t+1}$	$-(-0.17)$	$-(-0.08)$	$-(0.44)$	$-(0.13)$	$-(0.32)$
R.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{\infty} g_{t+j+1}$					0
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{\infty} \psi_{i,t}s_{i,t+1+j}$	$-(0.05)$	$-(-0.02)$	$-(0.05)$	$-(-0.02)$	$-(0.06)$
$\Delta\mathbb{E}_{t+1}\sum_{j=1}^{\infty} \psi_{i,t}r_{i,t+1+j}$	0.17	0.06	-0.48	-0.13	-0.39
$-\Delta\mathbb{E}_{t+1}\sum_{j=1}^{\infty} \pi_{t+1+j}$					$-(-0.1)$

Note: The unexpected inflation decomposition follows from the identity in Eq. (7). The first two rows report the left hand side (L.H.S.) of Eq. (7) for each country, and their sum in the last column of the table. These terms are balanced by the right hand side (R.H.S.) of Eq. (7) in the last three rows for each country, and their sum in the last column of the table. Numbers are computed draws by draw, and the means across all draws are reported. Number of draws: 572.

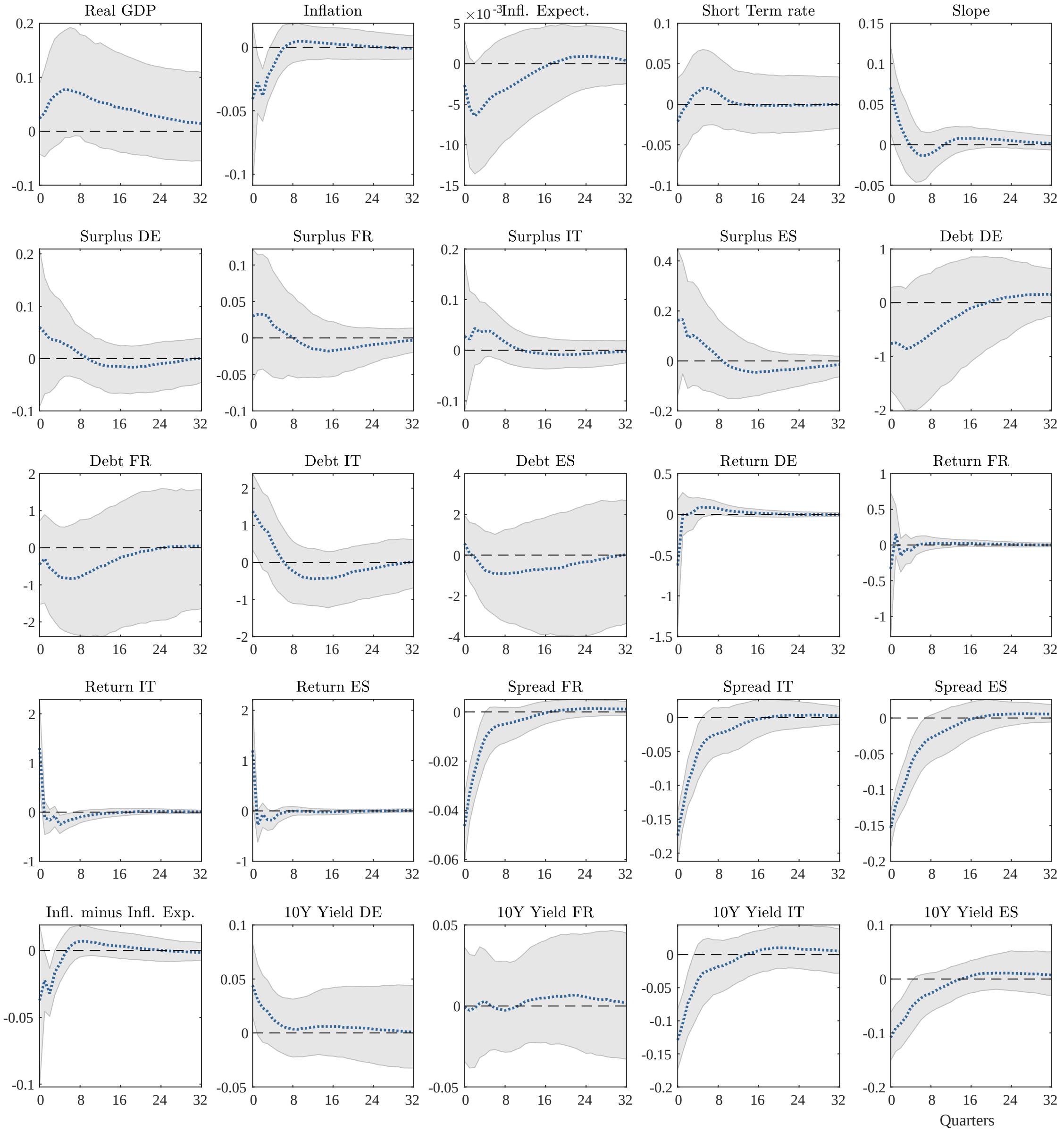
frequency, in price dynamics. However, our results indicate that, conditional on monetary policy shocks, national inflations adjust in a rather homogenous manner. The other results do not change substantially.

Figure 5: Unconventional Monetary Policy Shock



Note: The figure shows impulse response functions to a one standard deviation unconventional monetary policy shock (easing) in the Euro Area, using the larger model in which surplus, debt, and return for the four countries enter the VAR individually. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflation, inflation expectation, short-term rate, slope, returns, spreads, and yields correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Number of draws: 1125.

Figure 6: Convertibility Shock



Note: The figure shows impulse response functions to a one standard deviation convertibility shock (easing) in the Euro Area, using the larger model in which surplus, debt, and return for the four countries enter the VAR individually. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflation, inflation expectation, short-term rate, slope, returns, spreads, and yields correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Number of draws: 572.

6 Conclusion

We have proposed an empirical framework to study the adjustment dynamics through primary deficits, yields and returns, the market value of the debt and inflation, conditional to unexpected monetary policy changes aiming at the short interest rate (conventional), and the long interest rate or the spreads (unconventional).

The framework recognises that monetary-fiscal interactions – a topic of recent policy focus – can be studied by exploiting the long-term general government budget constraint as an identity, while obtaining the short-medium run dynamics from a rich Structural VAR model. We discuss the way in which the long term budget constraint can be understood in a monetary union with different fiscal authorities and a single monetary authority. However, we do not impose on the data any particular equilibrium model and remain agnostic about the size and nature of frictions and rigidities in the economy.

Letting the 'data speak' in a short sample over which monetary policy has gone through big changes is challenging. As a consequence, results depend on identification choices that by nature are controversial. Nevertheless, our result is insightful since it points to the fact that the nature of the fiscal-monetary interaction depends on whether unexpected monetary policy affects the short term interest rate (conventional) or the long end of the yield curve (unconventional). Key in this difference are two factors: (i) the effect on the return on the value of the debt, which depends on the change in yields at the relevant maturity, and (ii) the response of the primary surplus which depends on fiscal policy.

Non standard monetary policy has a larger effect on returns since, given the average debt maturity, long-term yields changes have a higher impact on returns than short rates. In the long-run, the shock is absorbed by a small effect on inflation – about half than in the case of conventional policy – and a change in returns which is 10 times higher than in the case of conventional policy. The primary surplus hardly moves.

It is difficult to extract a clear policy message from these results. The mechanism related to the budget identity is telling us that many factors affect inflation in the long-run: debt maturity, yields and primary surplus. In principle, coordination between monetary and fiscal policy could determine the combination of these factors, given an inflation objective. Historical data suggest that the small effect of unconventional monetary policy on inflation is explained by an unresponsive fiscal policy.

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A Returns, Yields and Monetary Policy

To provide a cleaner interpretation of how monetary policy affects returns and the market value of the outstanding government debt portfolio, it is helpful to map returns into bond prices and bond yields.

We start by recapping some basic bond maths. Denote the log nominal price of an n-period zero coupon bond at time t as $p_t^{(n)}$. Define the 1-period holding log return of this bond as

$$r_{t+1}^{(n)} \equiv p_{t+1}^{(n-1)} - p_t^{(n)} \tag{13}$$

Solve forward this equation until period n, and recall that at that time $p_t = \ln(1) = 0$

$$p_t^{(n)} = -[r_{t+1}^{(n)} + r_{t+2}^{(n-1)} + \cdots + r_{t+n}^{(1)}] = -\sum_{j=0}^{n-1} r_{t+j+1}^{(n-j)} \tag{14}$$

Applying expectations to both sides

$$p_t^{(n)} = -\mathbb{E}_t \sum_{j=0}^{n-1} r_{t+j+1}^{(n-i)} \tag{15}$$

then

$$(\mathbb{E}_{t+1} - \mathbb{E}_t) r_{t+1}^{(n-1)} = -(\mathbb{E}_{t+1} - \mathbb{E}_t) \sum_{j=1}^{n-1} r_{t+j+1}^{(n-j)} \tag{16}$$

A surprise log return today corresponds mechanically to a sequence of negative log returns from now to the maturity of the bond. To link returns to yields, note that for a zero-coupon bond yield this is simply

$$r_{t+1}^{(n)} = p_{t+1}^{(n-1)} - p_t^{(n)} = n y_t^{(n)} - (n-1) y_{t+1}^{(n-1)} \tag{17}$$

$y_{t+1}^{(n-1)}$ can be approximated by $y_{t+1}^{(n)}$: the yield of a 39 period bond is almost the same as a 40 period bond.[15]

B Data

B.1 General Principles

Our goal is to construct a quarterly, seasonally-adjusted, fiscal dataset including primary deficits and debt at market value for the four largest Euro Area economies (Germany, France, Italy and Spain). We start by using the current data available from international organisations such as the International Monetary Fund or Eurostat. To reconstruct the historical series starting in 1991, we use annual series which are temporally disaggregated using the conceptually closest possible high-frequency concept using the Chow-Lin method. After removing outlier observations, we seasonally adjust using X13.

B.2 Debt at Market Value

Our baseline series are the quarterly Debt at Market Value provided by the International Financial Statistics of the IMF. These are available from Q1 1999. To reconstruct them for the period 1995-1998, we start with annual data for the Annual Consolidated Financial Accounts by Institutional Sector (Total Financial Liabilities of the General Government). These are temporally disaggregated using the Chow-Lin method, using national sources for discontinued ESA 1995 tables of the the non-consolidated financial accounts (Total Financial Liabilities of the General Government), except for Italy where

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[15] Treasury bonds are usually coupon bonds. For a coupon bond, Campbell et al. (1997) approximate this as

$$r^{(n)}_{c,t+1} \approx D y^{(n)}_{c,t} - (D-1) y^{(n-1)}_{c,t+1} \tag{18}$$

where the duration is used instead of the maturity, and can be approximated $D \approx \frac{1-\rho^n}{1-\rho}$ and $\rho = (1+\bar{Y}_c)^{-1}$. For instance, in the sample we have n is about 40 quarters and D is about 30 quarters. This highlights that the duration of a coupon bond is lower than the maturity, as coupon payments skew the cash flows towards the present.

it comes from the OECD Government Statistics (Memorandum Item: debt securities in market value). For Germany and Spain, the latter series are also used for the period 1991-1994. For France in this period, we used discontinued tables for the Financial Accounts available from the Banque de France ("Long Time series, base 2000", Outstanding Amounts).[16] For Italy, we use the "Historical Tables (1950-1994), General Government Financial Liabilities TSCF0020" for the Financial Accounts, available in the Banca d'Italia website. The annual series is converted to euros and interpolated with the Chow-Lin method using the quarterly government debt at face value time series.

B.3 Primary Deficit

Germany. The baseline series come from Eurostat (Quarterly Integrated Economic Account, Non-Financial Accounts, General Government), starting in 1999. We add interest expense to the Net Lending/Borrowing series to obtain the primary deficit, and seasonally adjust using the X13 method. For the period 1991-1998, the annual data starting in 1970 from the Deutsche Bundesbank (General Government net lending/borrowing, as well as Interest Expenditure, National Accounts Concept, ESA 2010) are temporally disaggregated using the quarterly General Government net lending/borrowing series from the Federal Statistics Office (1991 onwards) and the Chow-Lin method. We remove the following outliers: 110bn in Q1 1995, 14bn in Q3 1995, 33bn in Q3 2010. These correspond to 125bn in 1995 related to the debts accumulated by the Treuhand agency for the privatisation of Eastern Germany public corporations, and 33 bn in 2010 related to financial market support measures.[17] After removing the outliers, the series are spliced and seasonally adjusted using X13.

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[16] https://www.banque-france.fr/en/statistics/savings-and-national-financial-accounts/financial-accounts/financial-accounts-and-financial-balance-sheets/national-financial-accounts-time-series

[17] For more information, see "Maastricht debt: methodological principles, compilation and development in Germany", Deutsche Bundesbank Monthly Report, April 2018, pp. 57-77.

France. We use directly the quarterly series on net lending/borrowing and interest expenditures from INSEE, which are seasonally adjusted by the source and start in 1950.

Italy. The baseline series come from Eurostat (Quarterly Integrated Economic Account, Non-Financial Accounts, General Government), starting in 1999. We add interest expense to the Net Lending/Borrowing series to obtain the primary deficit, and seasonally adjust using the X13 method. For the period 1991-1998, the annual data starting in 1980 from Istat (General Government net lending/borrowing, as well as Interest Expenditure, National Accounts Concept, ESA 2010) are temporally disaggregated using the series "General government borrowing requirement net of debt settlement and privatization receipts" from Banca d'Italia and the Chow-Lin method. The series are then seasonally adjusted and spliced.

Spain. Quarterly data for the primary government balance from the Intervencion General de la Administracion del Estado (IGAE) matches the series published by Eurostat and starts in 1995. This is seasonally adjusted using the X13 method. For the period 1991-1999, the annual data starting in 1980 from the International Monetary Fund World Economic Outlook (General Government Primary Net Lending/Borrowing, Bil. Euro) are temporally disaggregated using the discontinued tables for the Financial Accounts by Institutional Sector (ESA 1995), General Government, Net Financial Transactions. The following outlier is removed: 29.8bn in Q4 2012, corresponding to the European Financial Assistance Program. After removing the outliers, the series are spliced and seasonally adjusted using X13.

B.4 Debt-deficit adjustments

In line with our judgemental removal of the extraordinary items in the primary deficit, we adjust the series for debt accordingly. The cumulative impact of the aforementioned outliers is removed from the level of debt. Moreover, for Germany, the cumulative impact of 171 bn. euro, which was accounted in the debt but not in the deficit, is removed from 2010 Q4 onwards. This relates to the assumption of toxic assets belonging to HRE by the state-owned "bad bank" FMS Wertmanagement (FMSW). The debt series are Seasonally Adjusted using X13 after the removal of outliers.

B.5 Returns on the government debt portfolio

Based on the series for debt at market value and primary deficits, the returns can be backed out using the following equation:

$$(1 + R_t^i) = \frac{V_t^i + S_t^i}{V_{t-1}^i} \tag{19}$$

B.6 Other Macroeconomic Data

1. **Euro Area Nominal GDP.** Eurostat (1999-2019) and Euro Area Business Cycle Network Area Wide Model Data Base (1991-1998).

2. **Euro Area GDP Deflator.** Eurostat (1999-2019) and Euro Area Business Cycle Network Area Wide Model Data Base (1991-1998).

3. **Euro Area Inflation.** Eurostat. Overall HICP Excluding energy & unprocessed food. Converted to quarterly frequency using monthly averages.

4. **Long-Term Interest Rates.** OECD Main Economic Indicators (MEI), 10 year government bond yield (benchmark) for Germany, France, Italy, and Spain.

Converted to quarterly frequency using end-of-quarter data.

5. **Short-term interest rates.** Refinitiv (1999-2019). Euro 3-Month Overnight Interest Rate Swap. Converted to quarterly data from daily using averages for the last month of each quarter. Eurostat (1991-1999) EA11-19 average: 3-Month Money Market Interest Rate.

6. **Inflation Expectations.** Consensus Economics. Average of years 1-10 expectations for each country-quarter[18], then aggregated to a single series.[19]

7. **Oil prices.** Brent crude oil. US Energy Information Administration.

8. **EUR/USD Exchange Rate**. Federal Reserve Board, converted to quarterly using end-of-quarter data.

9. **Unemployment Rate.** Eurostat. EA-19 harmonised unemployment rate.

10. **Individual Country Nominal GDP.** National statistical offices.

11. **Individual Country Core Inflation.**

    - *Germany.* Eurostat (1995-2019) CPI ex energy and unprocessed food. Deutsche Bundesbank (1991-1994) GDP deflator.
    - *France.* Eurostat (1991-2019) CPI ex energy and unprocessed food.
    - *Italy.* Eurostat (1991-2019) CPI ex energy and unprocessed food.
    - *Spain.* Eurostat (1992-2019) CPI ex energy and unprocessed food. Instituto Nacional de Estadistica (1991-1992) Consumer Price Index excluding unprocessed food and energy products.

    In all cases converted to quarterly using monthly averages.

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[18] Interpolation in the first part of the sample where surveys were only done twice a year.

[19] Weighted average without Spain from 1991 to 1994 due to missing data.

B.7 Final data transformations

B.7.1 Small VAR

In the small VAR with aggregates only, the data are entered after the following transformations:

1. Real GDP growth: $400 \cdot \Delta\left(\log\left(\text{Nominal GDP}_t^{EA}\right) - \log\left(\text{GDP Deflator}_t^{EA}\right)\right)$[20]
2. Inflation minus Inflation Expectation: $400 \cdot \Delta\left(\log\left(\text{GDP Deflator}_t^{EA}\right)\right) - \pi^e$
3. Inflation expectation (in %): π^e
4. Short-term interest rate (in %)
5. Slope: long-term interest rate[21] minus short-term interest rate
6. Surplus[22]: $400 \cdot \left(\frac{\text{Primary Surplus}_t}{\text{Nominal GDP}_t^{EA}}\right) \cdot \left(\frac{\text{Nominal GDP}_{ss}^{EA}}{\text{Market Value of Debt}_{ss}}\right)$[23]
7. Debt[24]: $400 \cdot \log\left(\frac{\text{Market Value of Debt}_t}{\text{Nominal GDP}_t^{EA}}\right)$[23]
8. Return: $400 \cdot \log(1 + R_t)$

B.7.2 Large VAR

In the large VAR, the data are entered after the following transformations:

1. Real GDP growth: $400 \cdot \Delta\left(\log\left(\text{Nominal GDP}_t^{EA}\right) - \log\left(\text{GDP Deflator}_t^{EA}\right)\right)$
2. Inflation minus Inflation Expectation: $400 \cdot \Delta\left(\log\left(\text{GDP Deflator}_t^{EA}\right)\right) - \pi^e$
3. Inflation expectation (in %): π^e

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[20] We use seasonally adjusted core HICP to deflate GDP.

[21] 10Y government interest rate at the Euro Area level

[22] Primary surplus as aggregation of the four countries.

[23] To interpret orders of magnitude, recall that GDP is quarterly.

[24] Debt value as aggregation of the four countries.

4. Short-term interest rate (in %)

5. Slope: German long-term interest rate minus short-term interest rate

6. Surpluses: $400 \cdot \left(\frac{\text{Primary Surplus}_t^i}{\text{Nominal GDP}_t^{EA}}\right) \cdot \left(\frac{\text{Nominal GDP}_{ss}^{EA}}{\text{Market Value of Debt}_{ss}^i}\right)$[23]

7. Debts: $400 \cdot \log\left(\frac{\text{Market Value of Debt}_t^i}{\text{Nominal GDP}_t^{EA}}\right)$[23]

8. Returns: $400 \cdot \log(1 + R_t^i)$

9. Spreads: long-term interest rates minus German long-term interest rate

B.7.3 Extension

In the extension in Appendix C, the data are entered after the following transformations:

1. Real GDP growth: $400 \cdot \Delta\left(\log\left(\text{Nominal GDP}_t^{EA}\right) - \log\left(\text{GDP Deflator}_t^{EA}\right)\right)$

2. Inflations minus Inflation Expectation: $400 \cdot \Delta\left(\log\left(\text{GDP Deflator}_t^i\right)\right) - \pi^e$

3. Inflation expectation (in %): π^e

4. Short-term interest rate (in %)

5. Slope: German long-term interest rate minus short-term interest rate

6. Surpluses: $400 \cdot \left(\frac{\text{Primary Surplus}_t^i}{\text{Nominal GDP}_t^{EA}}\right) \cdot \left(\frac{\text{Nominal GDP}_{ss}^{EA}}{\text{Market Value of Debt}_{ss}^i}\right)$[23]

7. Debts: $400 \cdot \log\left(\frac{\text{Market Value of Debt}_t^i}{\text{Nominal GDP}_t^{EA}}\right)$[23]

8. Returns: $400 \cdot \log(1 + R_t^i)$

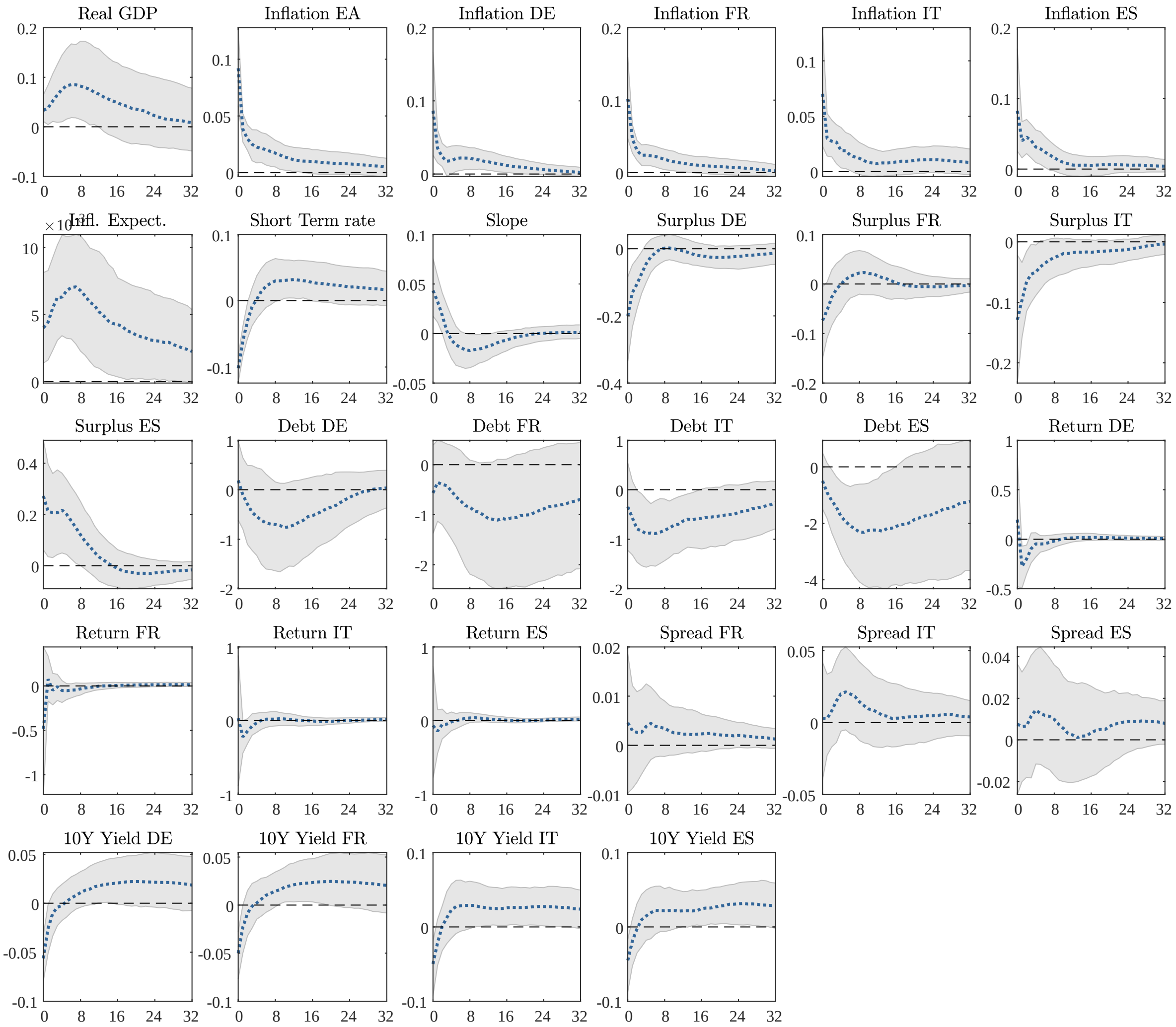
9. Spreads: long-term interest rates minus German long-term interest rate

C Additional Results

In this appendix we report results from a VAR with country-specific inflation. This to provide evidence on the potential differential adjustment, at business cycle frequency, in price dynamics. Results indicate that, conditional on monetary policy shocks, national inflation adjust in a homogenous manner.

C.1 Conventional Monetary Policy Shock

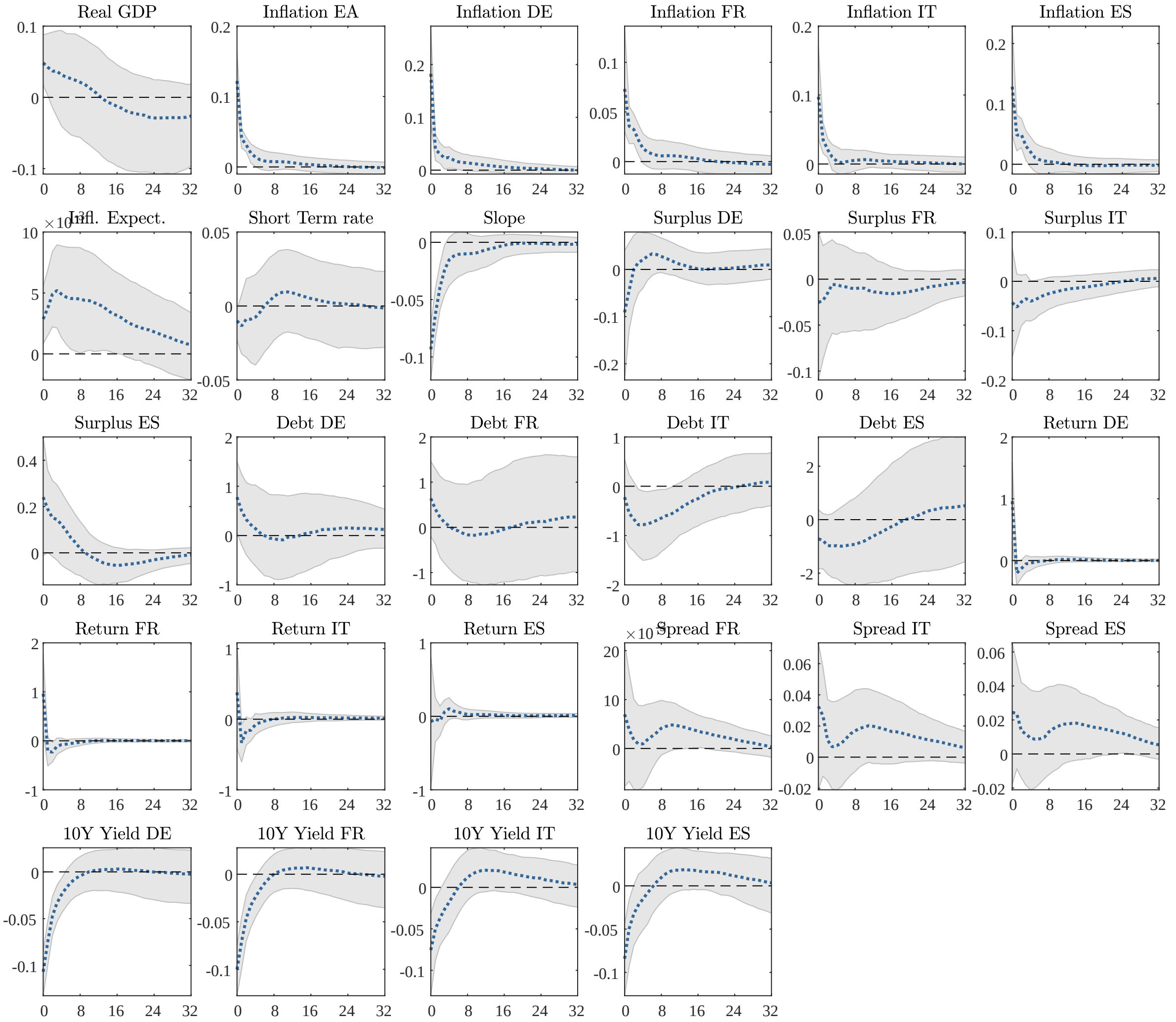
Figure 7: Conventional Monetary Policy Shock



Note: The figure shows impulse response functions to a one standard deviation conventional monetary policy shock (easing) in the Euro Area, using the largest model in which inflation, surplus, debt, and return for the four countries enter the VAR individually. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflations, inflation expectation, short-term rate, slope, returns, spreads, and yields correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Draws implying a root greater than 0.99 are discarded here. Number of draws: 296.

C.2 Unconventional Monetary Policy Shock

Figure 8: UNCONVENTIONAL MONETARY POLICY SHOCK



Note: The figure shows impulse response functions to a one standard deviation unconventional monetary policy shock (easing) in the Euro Area, using the largest model in which inflation, surplus, debt, and return for the four countries enter the VAR individually. The impulse response of real GDP is reported in level, i.e. as percentage deviation from the steady state. All other impulse responses are reported as deviations from the steady state. Variables are defined as described in Appendix B, so the impulse response of inflations, inflation expectation, short-term rate, slope, returns, spreads, and yields correspond to annualised percentage-point deviations from the steady state. The dotted lines report pointwise medians across all draws, whereas the bands correspond to the 16% and 84% percentiles. Draws implying a root greater than 0.99 are discarded here. Number of draws: 675.

Table 4: NATIONAL INFLATION DECOMPOSITION AT 32 QUARTERS – CONVENTIONAL MP SHOCK

Variable / Country	Germany	France	Italy	Spain	**Total**
L.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$\Delta\mathbb{E}_{t+1}\psi_{i,t}\pi_{i,t+1}$	0.03	0.03	0.03	0.01	0.09
$-\Delta\mathbb{E}_{t+1}\psi_{i,t}r_{i,t+1}$	$-(0.05)$	$-(-0.09)$	$-(0.02)$	$-(-0.01)$	$-(-0.04)$
R.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{31} g_{t+j+1}$					$-(0.06)$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{31} \psi_{i,t}s_{i,t+1+j}$	$-(-0.28)$	$-(0)$	$-(-0.31)$	$-(0.2)$	$-(-0.39)$
$\Delta\mathbb{E}_{t+1}\sum_{j=1}^{31} \psi_{i,t}r_{i,t+1+j}$	-0.16	-0.1	-0.11	0.02	-0.35
$-\Delta\mathbb{E}_{t+1}\sum_{j=1}^{31} \psi_{i,t}\pi_{i,t+1+j}$	$-(0.12)$	$-(0.12)$	$-(0.13)$	$-(0.05)$	$-(0.42)$

Note: The unexpected inflation decomposition follows from the identity in Eq. (7). The first two rows report the left hand side (L.H.S.) of Eq. (7) for each country, and their sum in the last column of the table. These terms are balanced by the right hand side (R.H.S.) of Eq. (7), in the long run. However, here the last rows display truncated sums instead of infinite sums. Moreover, draws implying a root greater than 0.99 are not discarded here, as our focus is business cycle dynamics. Numbers are computed draws by draw, and the means across all draws are reported. Number of draws: 440.

Table 5: National Inflation Decomposition at 32 Quarters – Unconventional MP Shock

Variable / Country	Germany	France	Italy	Spain	**Total**
L.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$\Delta\mathbb{E}_{t+1}\psi_{i,t}\pi_{i,t+1}$	0.05	0.02	0.03	0.02	0.12
$-\Delta\mathbb{E}_{t+1}\psi_{i,t}r_{i,t+1}$	$-(0.26)$	$-(0.27)$	$-(0.13)$	$-(0.00)$	$-(0.67)$
R.H.S. Eq. (7)					$\sum_{\mathbf{i}}$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{31} g_{t+j+1}$					$-(-0.18)$
$-\Delta\mathbb{E}_{t+1}\sum_{j=0}^{31} \psi_{i,t}s_{i,t+1+j}$	$-(0.06)$	$-(-0.13)$	$-(-0.18)$	$-(0.02)$	$-(-0.23)$
$\Delta\mathbb{E}_{t+1}\sum_{j=1}^{31} \psi_{i,t}r_{i,t+1+j}$	-0.08	-0.24	-0.15	0.07	-0.4
$-\Delta\mathbb{E}_{t+1}\sum_{j=1}^{31} \psi_{i,t}\pi_{i,t+1+j}$	$-(0.09)$	$-(0.04)$	$-(0.04)$	$-(0.02)$	$-(0.19)$

Note: The unexpected inflation decomposition follows from the identity in Eq. (7). The first two rows report the left hand side (L.H.S.) of Eq. (7) for each country, and their sum in the last column of the table. These terms are balanced by the right hand side (R.H.S.) of Eq. (7), in the long run. However, here the last rows display truncated sums instead of infinite sums. Moreover, draws implying a root greater than 0.99 are not discarded here, as our focus is business cycle dynamics. Numbers are computed draws by draw, and the means across all draws are reported. Number of draws: 2000.