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Macroprudential capital regulation and fiscal balances in the euro area [☆]

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A B S T R A C T

We examine the fiscal footprint of macroprudential policy in euro area countries arising through the *bond market channel* (Reis, 2021). Using local projections, we estimate impulse responses of the fiscal balance to an unexpected tightening in macroprudential capital regulation. Our findings suggest a dichotomy between country groups. In peripheral countries, the cyclically adjusted primary balance ratio deteriorates after a restrictive capital-based macroprudential policy shock. Since banks are important investors in domestic government debt, the shift in the public budget toward higher borrowing after the innovation might pose a threat to financial stability to the extent that sovereign risk increases. By contrast, in core countries, the cyclically adjusted primary balance ratio barely reacts to a sudden tightening in capital regulation.

1. Introduction

Macroprudential policy contributes to strengthening banks' resilience to shocks such as the recent COVID-19 crisis, particularly through capital-based instruments (ESRB, 2021a). However, as pointed out in a theoretical study by Reis (2021), this type of policy might have the unintended side effect of leaving a fiscal footprint. For instance, banks' incentives to invest in sovereign bonds might increase in response to a tightening of capital requirements, with the consequence of raising the price of these bonds and thereby potentially relaxing the government's budget constraint. Thus, macroprudential policy may leave a fiscal trace through a *bond market channel* by reducing sovereign borrowing costs (Reis, 2021). The attractiveness of government bonds is related to their favourable treatment in regulatory capital requirements. In many countries, such as the euro area, domestic sovereign bonds are assigned a zero-risk weight.

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However, by incentivising banks to increase their exposure to domestic government debt, macroprudential policy, for example a tightening of capital regulation, might contribute to strengthening the so-called *sovereign-bank nexus* (BCBS, 2017; Altavilla et al., 2017; IMF, 2014, 2018; Hristov et al., 2021), which is perceived as a core problem of the European debt crisis of 2010-2012, as it triggered *doom loops* (Acharya et al., 2014a; Brunnermeier et al., 2016; Farhi and Tirole, 2018; Dell'Ariccia et al., 2018). Particularly, banks' solidity in peripheral countries was strained by the downgrading of governments' creditworthiness, which induced a severe drop in the market value of sovereign bonds. Peripheral governments responded by providing safety guarantees to battered banks or even implementing substantial rescue packages. However, these increased sovereign risk (Acharya et al., 2014a). As a result, governments' creditworthiness declined further. Reis (2021) shows that if government finances are already in distress, a macroprudential tightening can be detrimental by increasing the likelihood of a fiscal crisis or doom loop. By contrast, if the sovereign is solvent, the stability of the banking sector might benefit from a higher exposure to public debt (Chari et al., 2020).

In this study, we examine the fiscal footprint of macroprudential policy in euro area countries arising through the *bond market channel*. Following Jordà (2005), we estimate local projections to derive impulse responses of important fiscal variables to shocks that proxy the unexpected component of macroprudential capital regulation. We distinguish between two groups of countries, namely the core and periphery. The analysis covers the period 2005-2018. As our sample is short, we use panel techniques.

In his theoretical model, Reis (2021) shows that macroprudential policy can leave a fiscal footprint through two channels beyond the *bond market channel*. First, macroprudential policy can operate through the *business cycle channel*. By affecting lending to the private sector, macroprudential measures can have an impact on aggregate activity which typically has consequences for government revenues and fiscal deficits. Second, macroprudential policy can have an impact through the *financial crisis channel* by reducing the likelihood and/or severity of financial crises and by affecting the costs associated with rescuing financial institutions in the event a crisis actually occurs. The three channels potentially coexist, making them difficult to disentangle. As discussed below, we address this identification problem by considering cyclically adjusted target variables as well as using specific indicators of fiscal and financial stress as control variables. In the current paper, we abstract from investigating both, the *business cycle channel* and *financial crisis channel*.[2]

Our findings suggest a dichotomy between the country groups. In peripheral countries, the cyclically adjusted primary balance ratio, that is, the cyclically adjusted primary balance as a percentage of GDP, deteriorates after a restrictive capital-based macroprudential policy shock. The worsening can be attributed to a simultaneous increase in the government's cyclically adjusted expenditure ratio and a decrease in the corresponding cyclically adjusted revenue ratio. Moreover, consistent with the theoretical mechanism discussed by Reis (2021), banks in peripheral countries increase their domestic sovereign bond holdings after a sudden tightening in macroprudential capital regulation. Thus, the volume of assets in bank portfolios that receive a regulatory zero-risk weight rises.

In core countries, the fiscal footprint is substantially weaker. The cyclically adjusted primary balance ratio responds sluggishly to a restrictive capital-based macroprudential policy shock, exhibiting a delayed and only short-lived deterioration. The cyclically adjusted expenditure ratio increases gradually, however, the rise is comparatively weak and accompanied by an increase in the corresponding revenue ratio. Moreover, banks in core countries decrease their domestic government bond holdings gradually after an unexpected tightening in macroprudential capital regulation.

Finally, in both country groups, the reactions of the cyclically adjusted primary balance ratio to a restrictive capital-regulation shock are state dependent. Particularly, the decline in that ratio is more pronounced when banks' holdings of domestic government bonds relative to total assets is comparatively large. Furthermore, in peripheral countries, there is evidence that capital markets have a disciplining effect; that is, a relatively high government debt ratio seems to create incentives to avoid a worsening of the cyclically adjusted primary balance ratio after stricter capital requirements.

Several empirical studies examine the response of the fiscal balance to innovations in government bond yields or spreads (Theofilakou and Stournaras, 2012; Legrenzi and Milas, 2013; de Groot et al., 2015; Born et al., 2020). The results suggest a disciplining effect of financial markets, indicating that fiscal consolidations occur under market pressure. Furthermore, the fiscal balance in peripheral countries of the euro area seems to improve on average in response to unconventional monetary policy shocks that bring down sovereign bond yields (Hülsewig and Rottmann, 2022). We add to this literature by investigating the effects of macroprudential policy shocks. Our study also contributes to the literature analysing the link between banks' asset portfolio choices in the euro area and macroprudential capital regulation (Acharya et al., 2014b; Acharya and Steffen, 2015; Gropp et al., 2019; Altavilla et al., 2017; Hristov et al., 2021). The results of these studies suggest that banks in peripheral countries increase their holdings of domestic government bonds in response to a tightening of capital requirements, with the effect being more pronounced for credit institutions with relatively low capitalization. This portfolio adjustment toward higher government debt contributes to strengthening the sovereign-bank nexus, thereby potentially posing risks to financial stability (Acharya et al., 2014b; Acharya and Steffen, 2015). Our analysis complements these findings by showing that macroprudential policy is indeed associated with a fiscal footprint arising through the *bond market channel*. Particularly, governments in peripheral countries shift to a more lenient fiscal stance after a restrictive shock in capital regulation.

[2] An analysis of the *business cycle channel* basically boils down to assessing the effects of macroprudential policy on aggregate credit and/or GDP. The results of numerous empirical studies looking at these effects, indicate that macroprudental tightenings put a downward pressure on credit volumes and GDP, at least in the short run (see, for example, Galati and Moessner (2018) and Budnik and Ruenstler (2022)). Regarding the *financial crisis channel*, constructing a solid empirical exercise is difficult given the small number of financial crises in the euro area over the past years and the corresponding difficulties in measuring their likelihood. Nevertheless, several studies provide indirect evidence by showing that a more restrictive macroprudential regulation can potentially reduce downside risks for GDP growth; that is, improve growth at risk (Duprey and Ueberfeldt, 2020; Franta and Gambacorta, 2020; Galan, 2020; Brandao-Marques et al., 2022).

The remainder of this study is organised as follows. Section 2 sets out the baseline model, introduces the data, and discusses the derivation of macroprudential policy shocks. Section 3 presents our results. First, we discuss the impulse responses of the baseline model to restrictive shocks to macroprudential capital regulation. Second, we examine the response of banks' demand for sovereign debt to the innovations. Third, we assess the robustness of our results. Finally, we estimate state-dependent impulse responses. Section 4 presents the conclusion.

2. Empirical model, data and macroprudential policy shocks

We estimate local projections to examine the reaction of fiscal variables to capital-based macroprudential policy shocks. We distinguish between two groups of euro area countries, the core and periphery.

2.1. Baseline model

Following Jordà (2005), the baseline model is given by:

$$X_{i,t+h} = \theta_h \mathrm{MPS}_{i,t} + \phi_h(L) Z_{i,t-1} + \zeta_h \mathrm{MPS}_{i,t} \times I_{i,t-1} + \alpha_{i,h} + u_{i,t+h}, \tag{1}$$

where $X_{i,t+h}$ is the variable of interest of country i, $\mathrm{MPS}_{i,t}$ is a shock to macroprudential policy, which measures the unsystematic component of macroprudential capital regulation, and θ_h is the coefficient corresponding to the shock. Moreover, $Z_{i,t-1}$ is a vector of control variables, $\phi_h(L)$ is a polynomial in the lag operator, ζ_h is the coefficient corresponding to the interaction between the shock and $I_{i,t-1}$, which is a vector of interaction variables, $\alpha_{i,h}$ captures country-fixed effects, and $u_{i,t+h}$ is an error term. In our baseline model, the variables of interest are the cyclically adjusted versions of the government's primary balance ratio, expenditure ratio and revenue ratio. The vector of control variables Z comprises lags of the government debt ratio, real output, a real measure of the stance of monetary policy, the banks' domestic government bond holdings ratio, and a measure of fiscal stress. The vector of interaction variables I includes the first lag of the banks' domestic government bond holdings ratio and government debt ratio. For every control variable in $Z_{i,t-1}$, we impose a lag order of four. The choice of the lag order takes account of the notion that fiscal adjustments are subject to time lags with respect to decision making and implementation (Born et al., 2018; Hülsewig and Rottmann, 2022).

We derive impulse responses to a capital-based macroprudential policy shock at time t by estimating a series of single regressions for each horizon $h = 0, 1, 2, ..., H$. For the calculation of standard errors, we use the method of Driscoll and Kraay (1998) which accounts for the serial correlation in the error terms induced by the successive leading of the dependent variable (Ramey and Zubairy, 2018). As in Tenreyro and Thwaites (2016), we set the maximum autocorrelation lag to $H + 1$.

2.2. Data

Since our sample is short, we adopt panel techniques. The group of core countries includes Austria, Belgium, Finland, France, Germany, and the Netherlands, while the peripheral countries comprise Ireland, Italy, Portugal, and Spain.[3] The panel approach allows us to pool the information within each country group, while controlling for heterogeneity across the units by taking account of country-fixed effects. The main advantage of the approach is that it increases the efficiency of the statistical inference.

In estimating separate panels of countries, we allow for possible structural heterogeneities between the two groups that appear a priori likely given the differences in terms of the economic development during our sample, which includes both the global financial crisis and European debt crisis. All countries in the euro area slipped into recession because of the global financial crisis. However, in peripheral countries, the economic downturn was more pronounced due to a substantial loss of international price competitiveness and sharp increase in public and/or private debt in the decade preceding the crisis. Furthermore, from 2010 on, peripheral sovereigns faced increasing difficulties in issuing bonds on international capital markets, leading to extraordinary financial distress. By contrast, core countries faced comparatively moderate recessions and benefited from their *safe-haven* status.

Our data are obtained from the ECB and comprise quarterly time series.[4] We consider the period 2005Q1-2018Q4. We focus on this period because the implementation of macroprudential policy measures was substantially more limited before 2005 and the macroprudential database does not extend beyond the end of 2018. The fiscal data comprise the cyclically adjusted versions of the following variables: the primary balance ratio, that is, the primary deficit or surplus as a percentage of GDP, the primary expenditure ratio, which corresponds to the difference between total expenditure and interest expenditure relative to GDP, as well as the revenue ratio, that is, the government total revenue as a percentage of GDP. Moreover, we use the government debt ratio, that is, government debt as a percentage of GDP. Real output is in logs.[5] The ECB's monetary policy stance is measured by the EURIBOR three-month rate. Following Cloyne et al. (2020), we construct a real indicator for monetary policy measures by calculating the difference between the EURIBOR three-month rate and first difference in the log of the Harmonised Index of Consumer Price (HICP). The banks' domestic

[3] We exclude Greece from our analysis, because it obtained external finance virtually only through financial aid programmes from May 2010 onwards.

[4] See Appendix A.1 for details on the data.

[5] Note that Irish GDP exhibits a shift of roughly 23% in 2015Q1 compared with the previous quarter. There was a shift in GDP because the country's low corporate tax rates attracted cooperation from some large multinationals to relocate their economic activity to the country. We consider the structural break in Irish GDP by smoothing the series; that is, we keep the dynamics of the series, but adjust for the shift.

government bond holdings ratio is calculated as the share of the holdings of domestic government bonds relative to total assets. The Sovereign Composite Indicator of Systemic Stress (SovCISS) is used as an indicator of fiscal stress. Finally, in extended specifications, we use additional bank balance sheet data in levels, as discussed below, the sovereign bond yield, and the Country-Level Index of Financial Stress (CLIFS) as an indicator of financial stress.

2.3. Cyclical adjustment of fiscal variables

As we are interested in identifying the governments' discretionary decisions on public debt, we cyclically adjust the fiscal variables by removing the part related to the aggregate business cycle. This allows us to separate the *bond market channel* from the *business cycle channel* (Reis, 2021).

We use the methodology of the European Commission (EC), according to which the cyclically adjusted component of the ratio of a nominal fiscal variable to nominal output is defined as (Mourre et al., 2019; Mourre and Poissonnier, 2019):

$$\left(\frac{X_{i,t}}{Y^n_{i,t}}\right)^{ca} = \frac{X_{i,t}}{Y^n_{i,t}} - \epsilon^X_i y^{gap}_{i,t},$$

where $y^{gap}_{i,t}$ is the real output gap of country i, $X_{i,t}$ is the respective fiscal variable, $Y^n_{i,t}$ is nominal output and ϵ^X_i is the semi-elasticity associated with X_i. The output gap is defined as:

$$y^{gap}_{i,t} = \frac{Y_{i,t} - Y^P_{i,t}}{Y^P_{i,t}},$$

where $Y_{i,t}$ denotes real output and $Y^P_{i,t}$ its potential level. We resort to the EC for the approximation of potential output and the semi-elasticities ϵ^X_i (Mourre et al., 2019).[6]

2.4. Capital-based macroprudential policy shocks

Macroprudential policy is aimed at safeguarding financial stability by counteracting the accumulation of systemic risks and vulnerabilities in the financial system and making it sufficiently resilient to various disturbances while, at the same time, being vigilant of the potential costs of any policy intervention in terms of economic activity. Accordingly, macroprudential authorities are supposed to tighten the instruments at their disposal when there are signs of elevated vulnerability and/or an inadequate degree of resilience.[7] Macroprudential authorities react to the information provided by numerous indicators of the soundness of the financial system like measures of indebtedness, credit spreads, asset price developments, financial stress, and the level of capital and liquidity buffers. Given this potential endogeneity of macroprudential policy, a simple regression of a target macroeconomic variable, for instance, the cyclically adjusted primary balance ratio, on actual macroprudential policy interventions would merely reflect correlations rather than a causal relationship. To uncover the latter, we need a measure of the unsystematic component of such interventions. In the following, we discuss the computation of this measure.

For each country group, we estimate a panel vector autoregressive (VAR) model of the form:

$$y_{i,t} = \sum_{j=1}^{p} B_j y_{i,t-j} + c_i + \varepsilon_{i,t}, \tag{2}$$

where $y_{i,t}$ is a vector of endogenous variables for country i, B_j is a matrix of autoregressive coefficients for lag j, p is the number of lags, c_i is a vector of country-specific intercepts, which account for possible heterogeneity across the units, and $\varepsilon_{i,t}$ is a vector of reduced-form residuals. The vector of endogenous variables includes an indicator for capital-based macroprudential policy measures, hereafter denoted by *MPI*, the Basel credit-to-GDP gap,[8] the lending spread, the CLIFS as an indicator for stress in financial markets, the bank capital ratio, and nominal house prices.[9] The choice of variables is based on the idea of reflecting the evolution of the financial cycle and financial conditions.

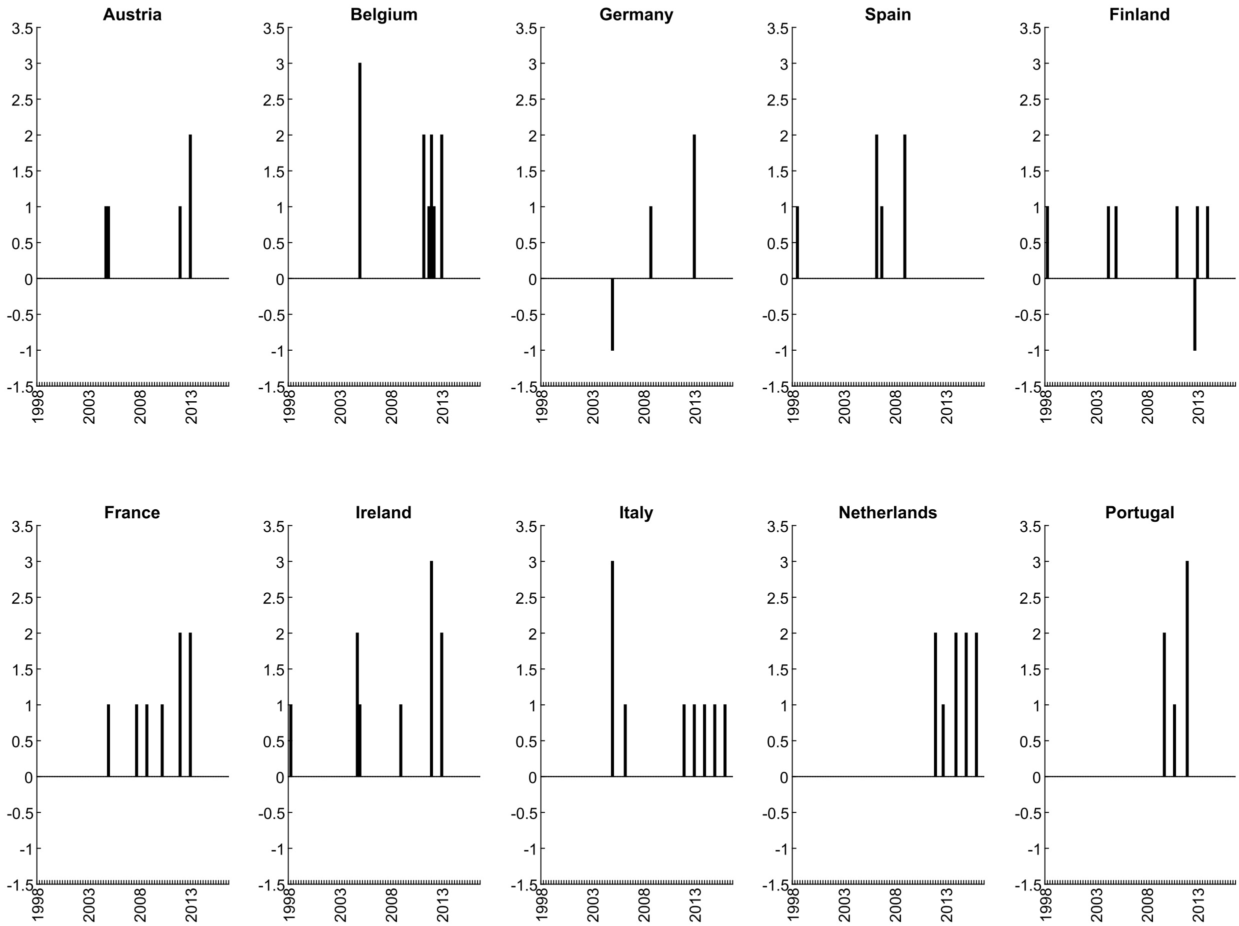
The panel VAR model (2) is estimated with Bayesian methods using a Normal-Wishart prior for the parameters and setting $p = 4$. Inference is based on 10,000 draws from the corresponding posterior distribution. The relationship between the structural shocks $\eta_{i,t}$ and the reduced-form residuals is governed by $\varepsilon_{i,t} = A_0\eta_{i,t}$, which holds for each cross-sectional unit and $\Sigma = A_0A_0'$. The structural shock related to capital-based macroprudential policy is identified by imposing a recursive ordering. This is implemented by assuming that the matrix A_0 corresponds to the lower triangular element in the Choleski factorisation of the variance-covariance

6 In addition, we consider alternative definitions of the cyclically adjusted component of the fiscal variables. We replace the real output gap by the cyclical component of real output derived with the Hodrick-Prescott filter with a smoothing parameter of 1,600. Moreover, regarding the cyclical adjustment of the fiscal variables, we alternatively approximate the cyclical-adjusted variables by the residuals of a linear regression of $X_{i,t}/Y_{i,t}$ on different lags of the real output gap. In all cases, our results remain qualitatively unchanged.

7 See Benes and Kumhof (2015), Angelini et al. (2014) and Boar et al. (2017) as well as ESRB (2019, 2021b, 2022), and ECB (2022), among others.

8 The Basel gap is the credit-to-GDP gap detrended by a one-sided Hodrick-Prescott filter with a smoothing parameter of $\lambda = 400{,}000$.

9 See Appendix A.2 for a description of the data. The lending spread is calculated as the difference between the loan rate and the three-month EURIBOR rate, where the loan rate is derived as the weighted average of the loan rate on loans extended to non-financial corporations and mortgage lending rate.



Notes: Capital-based macroprudential policy indicator of Hristov et al. (2021), which measures the changes in capital-based macroprudential policy.

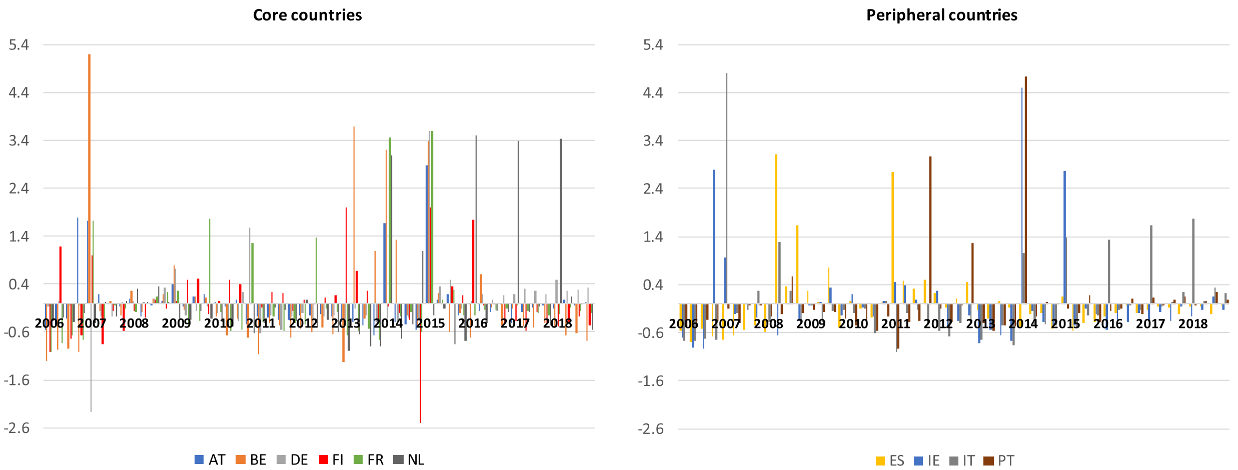
Fig. 1. Capital-based macroprudential policy indicator.

matrix Σ of ε_t. The *MPI* is ordered first and the corresponding orthogonal disturbance is interpreted as capturing the unsystematic component of capital-based macroprudential policy measures. The ordering implies that the *MPI* reacts only to its own shock on impact while responding to all other shocks with a lag of at least one quarter. This identification scheme is guided by the observation that macroprudential policy, unlike monetary policy, tends to be slow-moving.[10] For each period in our sample, we derive the structural shock as the mean over the 10,000 draws for that period. The innovations are standardised to have a mean of zero and standard deviation of one.

The *MPI* is taken from Hristov et al. (2021), who use the Macroprudential Policy Evaluation Database (MaPPED) provided by Budnik and Kleibl (2018) to construct the indicator. It comprises adjustments of (i) 'capital buffer requirements', (ii) 'loan-loss provisioning', (iii) 'minimum capital requirements' and (iv) 'risk weights'. Each individual policy change is assigned a value of +1 if it is a tightening, a value of -1 if it is a loosening, and of zero if the intervention is characterised as 'unspecified or with ambiguous impact' (Hristov et al., 2021). In case a country reports more than one policy change in a particular quarter, the associated discrete values are added up, resulting in the *net policy change* in that quarter. Fig. 1 displays the evolution of the net policy changes in each country. The *MPI* is constructed as the cumulative sum over the quarterly values.

Our analysis covers a period during which macroprudential authorities in the euro area countries mainly tightened bank capital requirements. Thus, in all member countries, the cumulated capital-based macroprudential policy indicator increase over time. However, in the local projections (1), the *MPI* is not used as the shock variable. Instead, we use the structural innovations from the estimated panel VAR model which we interpret as reflecting the country-specific unsystematic component of capital-based macroprudential policy regulation. Fig. 2 shows that these structural shocks are stationary with a mean of zero, taking both positive

[10] Reasons for this include phase-ins of macroprudential policies as well as decision and implementation lags due to difficulties to proxy the financial cycle or systemic risk (see Arslan and Upper, 2017) or a multiplicity of macroprudential authorities in countries (see Edge and Liang, 2022). Hristov et al. (2021) estimate very similar VARs and show that the results are qualitatively robust to alternative orderings of the *MPI*.



Notes: Structural shocks to capital-based macroprudential policy. The shocks are derived from structural panel VAR models as described in the text.

Fig. 2. Structural macroprudential policy shocks. (For interpretation of the colours in the figure(s), the reader is referred to the web version of this article.)

as well as negative values. A positive value of the structural innovations reflects that macroprudential policy was tighter than expected, while a negative value indicates that policy was looser than expected. Thus, although our analysis refers to a period that was characterized by a sequence of tightenings in bank capital regulation, the use of structural shocks allows us to examine the effects of the macroprudential policy that was unexpected.[11] Furthermore, the structural shocks are quite heterogeneous across the countries (see Fig. 2) and over time.

Finally, note that an important property of our *MPI* is that it implies a fully equivalent treatment of capital-based policy actions across types and magnitudes. Thus, the dummy-type *MPI* only reflects the *extensive margin* of capital-based interventions, that is, their frequency and direction, but not their *intensive margin*. Ideally, one would like to measure the intensity of these policies. However, it is not straightforward to obtain a fully quantitative policy indicator due to the limited comparability across countries and across measures (Kuttner and Shim, 2016; Cerutti et al., 2017; Akinci and Olmstead-Rumsey, 2018; Alam et al., 2019).[12] Given these issues, and given our objective of analyzing as broad a range of euro area countries and capital instruments as possible, we limit our analysis to the dummy indicator, which, despite its limitations, allows for a sufficient degree of comparability across measures and countries.

However, as pointed out by Akinci and Olmstead-Rumsey (2018), the use of a dummy-type *MPI* generates an attenuation bias for the coefficient estimates on the indicator.[13] Accordingly, our results presented below should be viewed as conservative, being biased towards a lower likelihood of finding a significant relationship between changes in capital-based macroprudential regulation and other macroeconomic variables.

3. Empirical results

3.1. Baseline model impulse responses

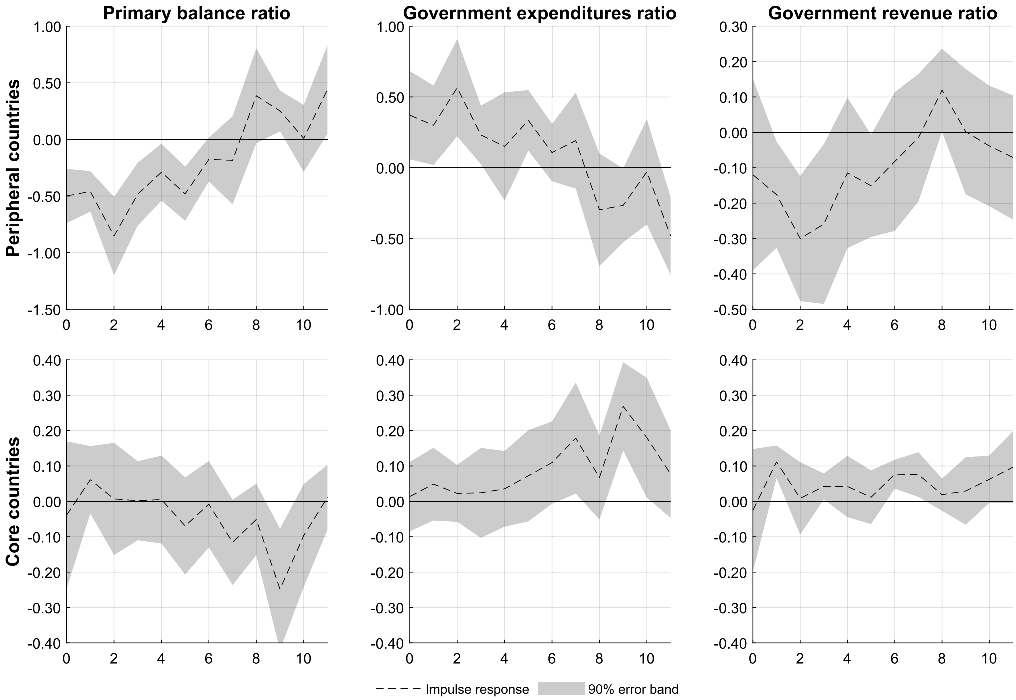
We estimate baseline model (1) for both groups of countries to obtain impulse responses to a sudden tightening of macroprudential capital regulation. In this Section, we focus on the linear effects of the shock via the term $\theta_h \text{MPS}_{i,t}$ in (1) and derive the impulse responses under the assumption that each interaction variable $I_{i,t-1}$ equals its pooled mean. Later, in Section 3.5, we provide an analysis of potential non-linearities, that is, when the variables in $I_{i,t-1}$ lie above or below the pooled mean.

Fig. 3 displays the results. The dashed lines are the estimated impulse responses and the shaded areas their 90% error bands. In peripheral countries, the cyclically adjusted primary balance ratio worsens after a restrictive capital-based macroprudential policy shock. The maximum drop to a one standard deviation macroprudential policy disturbance is approximately 0.85 percentage points, which is reached two quarters after the shock. The decline is related to both an increase in the cyclically adjusted primary expenditure ratio and a decrease in the cyclically adjusted revenue ratio.

[11] The analysis of the effects of unconventional monetary policy innovations builds on the same interpretation. In particular, the ECB's policy during the period 2008-2018 was almost entirely characterized by a sequence of unconventional loosenings. Nevertheless, as shown by various empirical studies, the unsystematic component of this unconventional policy path can be identified as the structural innovation in a VAR estimated over the same period.

[12] In particular, due to differences between the national legal frameworks, even seemingly similar macroprudential measures are often implemented quite differently and applied to different objects (e.g. specific types of loans) across jurisdictions. Furthermore, within the same country, aggregation over intensities of policy changes is hindered by mere heterogeneity across possible macroprudential measures.

[13] The attenuation bias stems from measurement error, as the indicator is an imperfect measure of the strength of macroprudential regulation. This measurement error worsens if one cannot perfectly distinguish between binding and non-binding measures, as is the case here.



Notes: Impulse responses to a restrictive capital-based macroprudential policy shock. The ratios are cyclically adjusted. Positive values of the cyclically adjusted primary balance ratio denote an improvement, negative values a deterioration. The variation in the ratios is measured in percentage points.

Fig. 3. Impulse responses to a restrictive macroprudential policy shock.

By contrast, in core countries, the cyclically adjusted primary balance ratio reacts only sluggishly to a restrictive capital-based macroprudential policy shock. The cyclically adjusted expenditure ratio increases gradually; however, the increase is comparatively modest and accompanied by an increase in the cyclically adjusted revenue ratio. Consequently, the primary balance ratio shows a short-lived deterioration of 0.25 percentage points around nine quarters after the shock.

3.2. Exploring the channel: banks' sovereign bonds demand

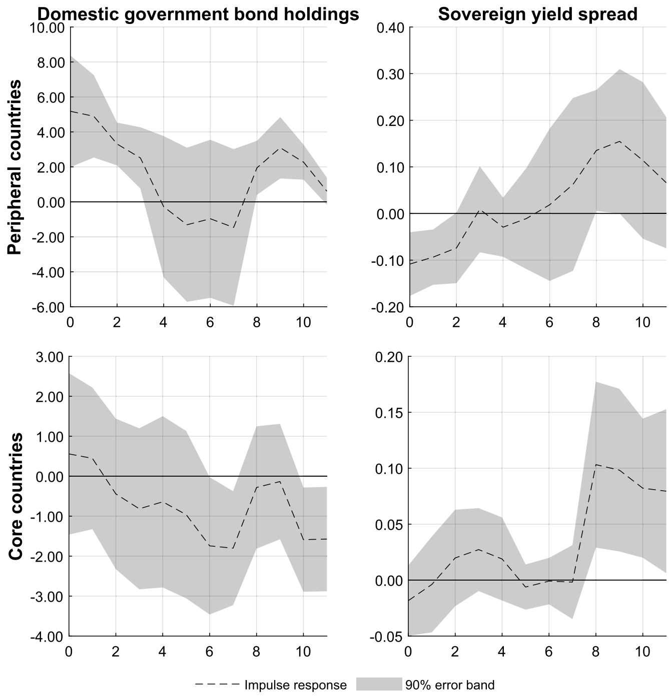
To gain insights into the mechanism underlying the fiscal reactions, we estimate the responses of banks' domestic sovereign bond holdings as well as that of the corresponding sovereign yield spread to a capital-based macroprudential policy shock. Regarding banks' domestic sovereign bond holdings, we employ a model similar to (1), where the control variables comprise the log of the volume of bank loans extended to private non-banks, the log of bank capital, the spread between the loan rate and government bond yield, the EURIBOR three-month rate as a measure for the conditions in the money market, and the SovCISS as a measure of the degree of fiscal stress.[14] We use four lags as in our baseline model. Regarding the reaction of the sovereign yield spread to a restrictive capital-based macroprudential policy innovation, we re-estimate baseline model (1), that is, using the same control variables. The spread is calculated as the difference between the yield on sovereign bonds and EURIBOR three-month rate.[15]

The impulse responses of the two additional variables to a restrictive macroprudential capital regulation shock are depicted in Fig. 4 together with the respective 90% error bands.

In peripheral countries, banks increase their exposure to sovereign debt in response to a restrictive macroprudential capital regulation shock. Domestic government bond holdings rise by approximately 5% on impact after the innovation. Thus, peripheral banks respond to a sudden tightening in macroprudential capital regulation by investing more in assets which receive a favourable treatment in the regulatory capital requirement. The sovereign yield spread falls by 0.1 percentage points on impact in response to the innovation.

[14] Since the variables of interest are in levels, we use bank balance sheet variables in levels as controls. The loan volume is calculated as the sum of the volume of loans extended non-financial cooperations and loans for housing purchases. The loan rate is again derived as the weighted average of the loan rate on loans extended to non-financial corporations and the mortgage lending rate.

[15] We focus on the sovereign yield spread instead of the absolute yield to take account of monetary policy measures. For instance, Mendicino et al. (2020) show in a calibrated model for the euro area that the policy rate declines after a restrictive shock to macroprudential capital regulation. For the US, Budnik and Ruenstler (2022) find that the federal fund rate also decreases in response to a tightening of capital requirements. Moreover, Eickmeier et al. (2018) conclude for the US that, historically, the Federal Reserve accommodated policy rates after capital requirement tightenings.



Notes: Impulse responses to a restrictive capital-based macroprudential policy shock. The variation in banks' domestic sovereign bond holdings is in percent. The variation in the sovereign bond spread is measured in percentage points.

Fig. 4. Responses of additional variables to a macroprudential policy shock.

By contrast, in core countries, banks decrease their domestic government bond holdings gradually in response to a restrictive shock to macroprudential capital regulation. The decline is approximately 1.7% after seven quarters.[16] The sovereign yield spread initially remains unchanged in response to the restrictive innovation, but as banks' holdings of domestic government bonds steadily decline, it starts to rise.

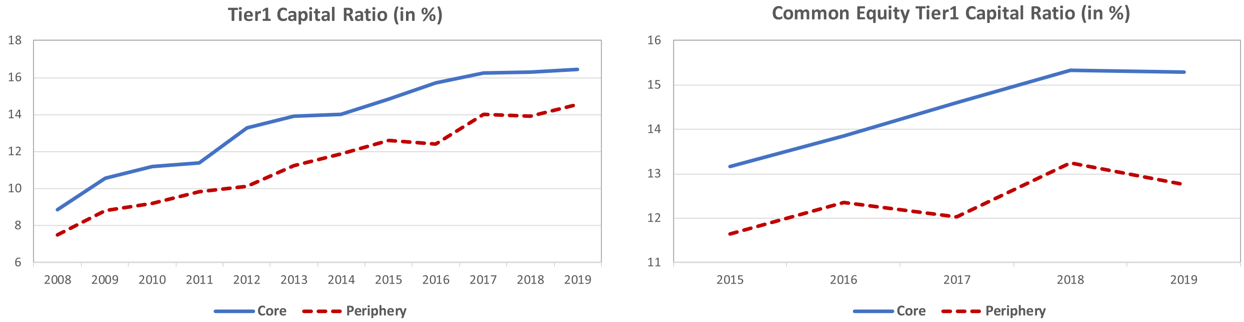
Overall, in both groups of countries, the macroprudential shock tends to push banks' holdings of domestic government bonds and the corresponding sovereign yield spreads in opposite directions. This suggests that the results are mainly driven by changes in banks' demand for public debt rather than changes in the supply of government bonds. This finding is consistent with the *bond market channel* of macroprudential policy proposed by Reis (2021), that is, by changing the demand for sovereign bonds, capital-based regulatory measures alter the government's borrowing cost, thus potentially enabling it to change its deficit policy. For peripheral countries, the results shown in Fig. 4 might serve as a demand-side explanation for the response of the cyclically adjusted primary fiscal balance ratio to a capital-based macroprudential shock (see Fig. 3). Particularly, the significant increase in banks' demand for public debt translates into a more pronounced primary deficit deterioration. Since banks are significant investors in sovereign debt (Arslanalp and Tsuda, 2014; Acharya and Steffen, 2015; BCBS, 2017; Ongena et al., 2019), the shift toward higher domestic government bond holdings in the periphery may exacerbate the adverse effects of the sovereign-bank nexus to the extent that sovereign risk rises. By contrast, in core countries, a strengthening of the nexus cannot be observed.

3.3. Discussion

Identification of the bond market channel Recall that the model of Reis (2021) suggests that macroprudential policy can have a fiscal footprint through three channels, that is, the *bond market channel*, *business cycle channel* and *financial crisis channel*. Disentangling the three channels is challenging. In our empirical analysis, we address this identification problem by resorting to a specific definition of the variables of interest as well as a specific set of control variables.

In the local projections, we eliminate the *business cycle channel* by using cyclically adjusted fiscal variables, that is, the variables' component that is independent of the business cycle. The cyclically adjusted fiscal variables are usually interpreted as reflecting discretionary changes in public expenditure and taxes. Moreover, we control for variations in real output and a real measure of

[16] Estimating baseline model (1) with the banks' domestic government bond holdings *ratio* as the variable of interest instead shows in analogy to Fig. 4 that the *relative* volume of sovereign debt in banks' portfolios increases temporarily in the periphery and falls temporarily in core after a tightening in capital-based macroprudential policy. The impulse responses are available upon request.



Notes: Regulatory capital as a percentage of risk-weighted assets. Weighted averages across countries in the corresponding country group. Each country-specific value is weighted by the ratio $TA_{i,t}/\sum_{i=1}^{N} TA_{i,t}$, where $TA_{i,t}$ are the total assets of country i's banks and $\sum_{i=1}^{N} TA_{i,t}$ are banks' total assets in the corresponding country group. The length of time series is restricted by the data availability. Source: ECB Statistical Data Warehouse.

Fig. 5. Regulatory capital ratios.

monetary policy. In this way, we control for any possible residual correlation between the cyclically adjusted fiscal variables and the business cycle. Similarly, we control for the *financial crisis channel*, which operates primarily by affecting *(i)* the probability that the government will have to bail out financial institutions and *(ii)* the size of those bailouts in the event of an actual crisis (Reis, 2021).[17] Our local projections include the SovCISS that measures fiscal tensions. Moreover, in the panel VAR model, we include the CLIFS that can be interpreted as to reflecting overall financial conditions (Holló et al., 2012; Duprey et al., 2015). These indicators have been shown to be good predictors of tail risks for economic activity at a horizon of up to several quarters.[18] Thus, the use of the SovCISS allows us to implicitly control for possible changes in the likelihood of bail-outs/crises. Moreover, our sample contains two episodes involving significant rescue packages for the financial sector, that is, the global financial crisis and the European sovereign debt crisis. Both, the SovCISS and CLIFS were strongly elevated during these episodes. Finally, at the individual country level, the SovCISS exhibits a substantial co-movement with the public bail-out expenditures in the period 2008-2018.

Differences between core and periphery countries Our results show that banks across country groups react differently to macroprudential policy innovations. Theoretically, the different responses could be due to differences in bank capitalization. For instance, the model of Crosignani (2021) suggests that banks with low capitalization have high exposure to domestic sovereign debt. An increase in banks' demand for domestic government bonds, for example, as a result of a tightening in capital requirements, lowers the interest rate on government bonds, which supports government debt capacity. In contrast, highly capitalized banks lend to private corporates rather than invest in sovereign bonds. Fig. 5 shows that banks in peripheral countries have comparatively weak capitalization.

Moreover, according to the capital buffer theory, banks choose an optimal capital ratio. The buffer corresponds to capital held in excess of the regulatory requirement (Buser et al., 1981; Marcus, 1984; Calomiris and Kahn, 1991; Calem and Rob, 1999). In this theory, banks face the trade-off between holding a higher capital buffer to reduce the probability of violating the minimum requirement, and incurring higher costs, as capital is more costly than insured deposits. In the face of tightening capital requirements, banks with high capital buffers aim to maintain their buffers by increasing both their capital and portfolio riskiness. In contrast, banks with low buffers tend to rebuild their buffers by reducing the riskiness of their asset portfolios while simultaneously attempting to raise capital by issuing equity or retained earnings.[19]

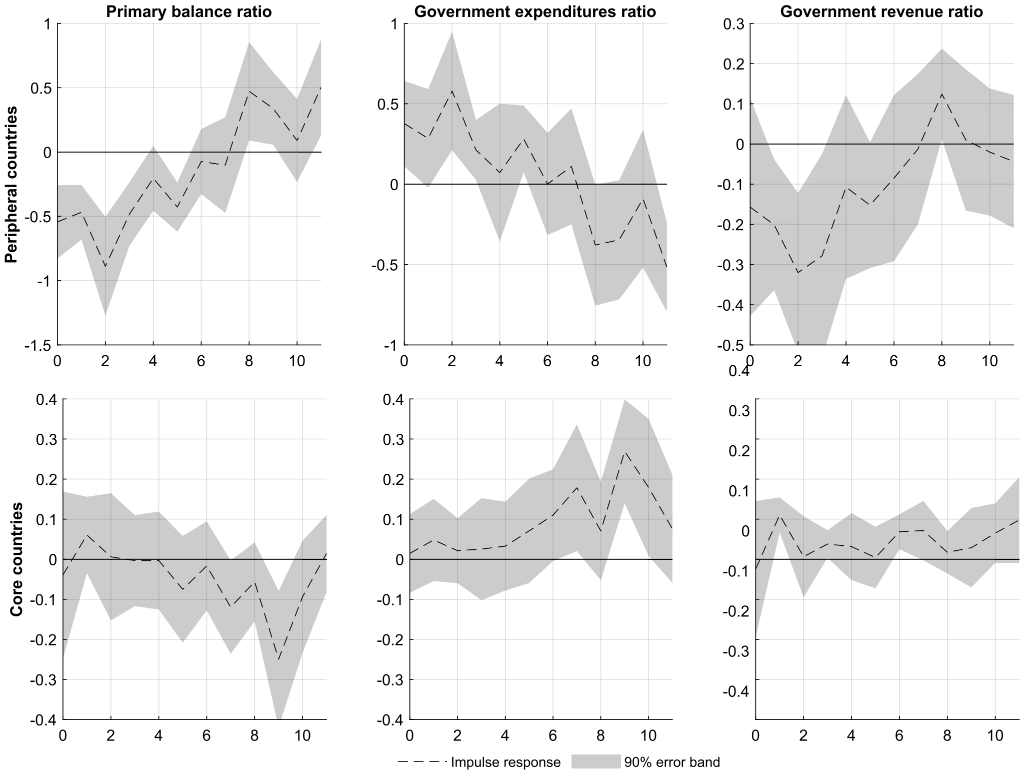
Therefore, according to theory, banks in core countries with a relative high capitalization (see Fig. 5) would respond to a tightening of capital-based macroprudential policy by increasing the riskiness of their portfolios, that is, by investing more in risky loans while reducing exposure to safer sovereign bonds. Banks in peripheral countries would initiate the opposite portfolio adjustment, which would be accompanied by an increase in demand for government bonds. Thus, differences in bank capitalization may explain our empirical results.

Alternative drivers of banks' demand for government bonds There are other reasons that may explain why banks in peripheral countries increased their demand for government bonds during the global financial crisis and the European sovereign debt crisis. The results of Ongena et al. (2019) point to the operation of a *moral suasion* channel. They find that in the course of the European sovereign debt crisis 2010-2013, domestic banks in fiscally stressed countries, that is, the peripheral countries, were considerably more likely than foreign banks to increase their holdings of domestic sovereign bonds in months with relatively high domestic sovereign bond issuance. Battistini et al. (2014), Ohls (2017) and Hardouvelis and Vayanos (2023), among others, also find evidence in support of

[17] Note that while it is highly unlikely that a macroprudential authority would be willing to tighten its stance in the midst of a crisis, the failure to loosen policy sufficiently would act as an macroprudential shock.

[18] See the growth-at-risk literature, for example Adrian et al. (2019), Duprey and Ueberfeldt (2020), Galan (2020), Figueres and Jarocinski (2020), Aikman et al. (2021), Adrian et al. (2022), Lang et al. (2023).

[19] A number of studies provide empirical evidence in support of such behavioural patterns – see Rime (2001) for Switzerland; Heid et al. (2004) for German savings banks; and Shrieves and Dahl (1992) as well as Jokipii and Milne (2011) for the US.



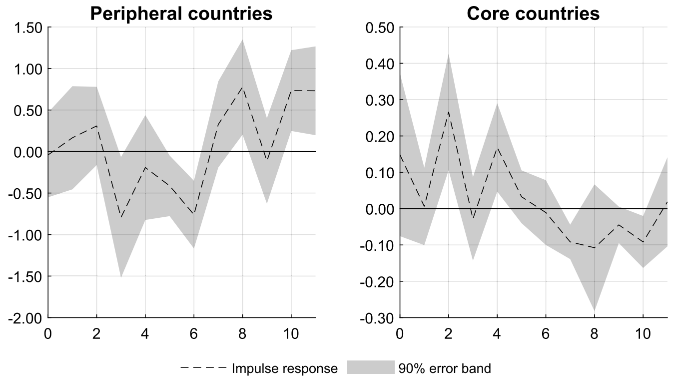
Notes: Impulse responses to a restrictive capital-based macroprudential policy shock derived from the baseline model extended by two crisis dummies added as additional controls. The ratios are cyclically adjusted. One dummy covers the global financial crisis (2008Q1-2009Q4) and the other covers the European sovereign debt crisis (2010Q1-2013Q4). Positive values of the cyclically adjusted primary balance ratio denote an improvement, negative values a deterioration. The variation in the ratios is measured in percentage points.

Fig. 6. Impulse responses of baseline model including crisis dummies.

the moral suasion hypothesis. Furthermore, in a theoretical model, Anand and Mankart (2020) show that risk-taking by banks can be related to sovereign default risk. An increase in banks' domestic government bond holdings improves the government's incentives to repay the debt and, thus, reduces sovereign bond rates. Particularly, when the government's debt level is high, banks' default also induces that the sovereign defaults. Thus, banks' investments in domestic government bonds can also be interpreted as a kind of *gamble for resurrection*, as the government has an incentive to service its debt. However, the literature suggests that both mechanisms, *moral suasion* and *gambling for resurrection* are largely crisis-related phenomena (Acharya and Steffen, 2015; Drechsler et al., 2016; Ongena et al., 2019; Ben-David et al., 2019; Peydro et al., 2021; Bidder et al., 2021, among others).

For our analysis, *moral suasion* and *gambling for resurrection* could be problematic as alternative explanations for our results only in the following two cases. First, if these behavioural mechanisms are reflected in the macroprudential policy shock. Second, if the shocks systematically coincide with the periods when significant *moral suasion* and/or *gambling for resurrection* was operative. Regarding the first case, the existing literature does not provide any evidence or economic reasons for why *moral suasion* and/or *gambling for resurrection* might be reflected in an indicator of capital-based macroprudential policy or the corresponding identified exogenous innovation. In addition, we control for financial stress by considering the CLIFS when identifying the shock. Hence, we view it unlikely that the macroprudential policy shock is contaminated. Furthermore, it is unlikely that the macroprudential policy innovations systematically coincide with episodes of sizable *moral suasion* and/or *gambling for resurrection*. First, the shocks are not concentrated in a specific period, for instance, the global financial crisis or sovereign debt crisis, but exhibit evolutions that are quite heterogeneous across countries (see Fig. 2) and over time. Second, by including the SovCISS in the local projections, we control for both crises, that is, the global financial crisis and sovereign debt crisis, and phenomena specific to these two episodes.

Nevertheless, we estimate a modified version of our baseline model (1) to support the claim that our macroprudential policy indicator does not simply reflect crisis-specific developments. Particularly, we extend the model by including two dummies that are the same for all countries. The first dummy is equal one during the global financial crisis (2008-2009) and zero otherwise, while the second dummy is equal one only during the sovereign debt crisis (2010-2013). The dummies act as period-specific fixed effects. Fig. 6 depicts the results. As can be seen, the impulse responses to a capital-based macroprudential policy shock are very similar to our baseline findings. Accordingly, it appears unlikely that our results are driven by *moral suasion* or *gambling for resurrection*, which are phenomena tightly related to the crisis episodes.



Notes: Impulse responses of the cyclically adjusted primary balance ratio to a restrictive non capital-based macroprudential policy shock. Positive values of the ratio denote an improvement, negative values a deterioration. The variation in the ratio is measured in percentage points.

Fig. 7. Impulse responses to a *non* capital-based macroprudential policy shock.

Non capital-based macroprudential policies In our analysis, we focus on the fiscal footprint of capital-based macroprudential policy. The main reason is the relative homogeneity of the capital-based measures contained in the policy database of Budnik and Kleibl (2018), which allows us to construct an interpretable common policy indicator. However, the database also comprises a variety of non capital-based measures, that is, *(i)* "Lending standards restrictions", *(ii)* "Liquidity requirements and limits on currency and maturity mismatch", *(iii)* "Limits on large exposures and concentration", *(iv)* "Levy/ Tax on financial institutions and activities" and *(v)* "Other measures" (Budnik and Kleibl, 2018; Hristov et al., 2021). The non capital-based measures are much more diverse, rendering the construction and interpretation of a corresponding aggregate policy indicator less straightforward. Nevertheless, the implementation of these measures may also leave a fiscal footprint, which we seek to examine. Therefore, we construct a macroprudential policy indicator termed MPI^{rest} that comprises the policy instruments through which non capital-based measures are implemented.

We estimate panel VAR models in which we replace the capital-based MPI with MPI^{rest} to generate structural innovations related to non-capital-based macroprudential policy measures. The structural innovations are then used for the estimation of the local projections. Fig. 7 displays the reaction of the cyclically adjusted primary balance ratio to an unexpected tightening in non capital-based macroprudential policy measures.

For both country groups, we find that the impulse responses of the cyclically adjusted primary balance ratio show no clear pattern in response to a non capital-based macroprudential policy shocks, that is, positive and negative values alternate. In core countries, there is a temporary improvement in the primary balance ratio, the cause of which, however, is difficult to interpret due to the heterogeneity of the non capital-based policy measures.

3.4. Robustness

We continue by performing a series of robustness checks.

Alternative monetary policy measures First, we re-estimate baseline model (1) using alternative measures of monetary policy. We use the shadow short-rate of Krippner (2013) in real terms instead of the real EURIBOR three-month rate.[20] Additionally, we expand the baseline model by including lags of the log of national central banks' total assets to control for unconventional monetary policy measures implemented in the form of government bond purchases.[21] Fig. 8 displays the impulse responses derived from the alternative model specifications together with the baseline-model 90% error bands.

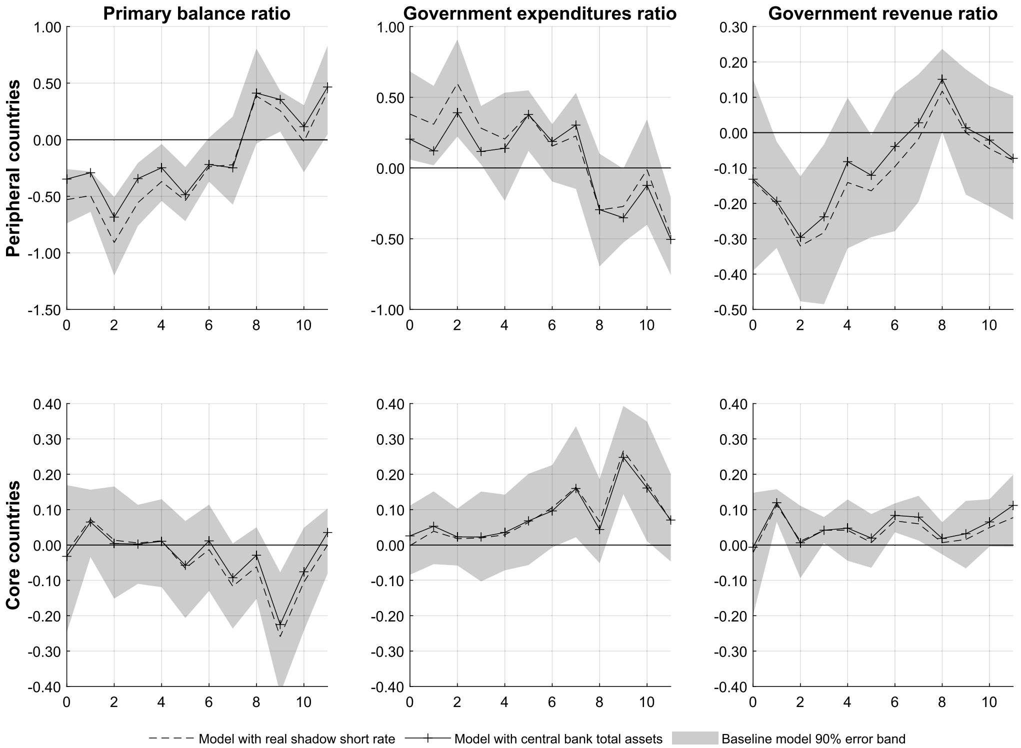
In peripheral countries, the deterioration of the cyclically adjusted primary balance ratio after a restrictive shock to macroprudential capital regulation is somewhat less pronounced in the model controlling for the log of central bank total assets. However, the differences in the impulse responses compared to those derived from the baseline model are only minor. All estimated impulse responses are well within the baseline model 90% error bands.

Alternative macroprudential policy shocks Second, we estimate alternative panel VAR models to generate capital-based macroprudential policy shocks. The specification of model (2) is supposed to reflect the macroprudential authorities' reaction function. However, there are additional financial indicators that might be relevant.

For this reason, we extend the model by including a number of such indicators, one at a time. These comprise the ratio of bank loans to nominal GDP instead of the Basel gap, real output, the stock price index covering the banking sector, bank credit default swaps, the banks' volume of loans extended to the private sector relative to total assets, the bank capital ratio, and the

[20] The real shadow short-rate is calculated as the difference between the shadow short-rate and the first difference in the log of the HICP.

[21] Consistent with baseline model (1), we use four lags of this additional control variable.



Notes: Impulse responses to a restrictive capital-based macroprudential policy shock. The ratios are cyclically adjusted. Positive values of the cyclically adjusted primary balance ratio denote an improvement, negative values a deterioration. The variation in the ratios is measured in percentage points.

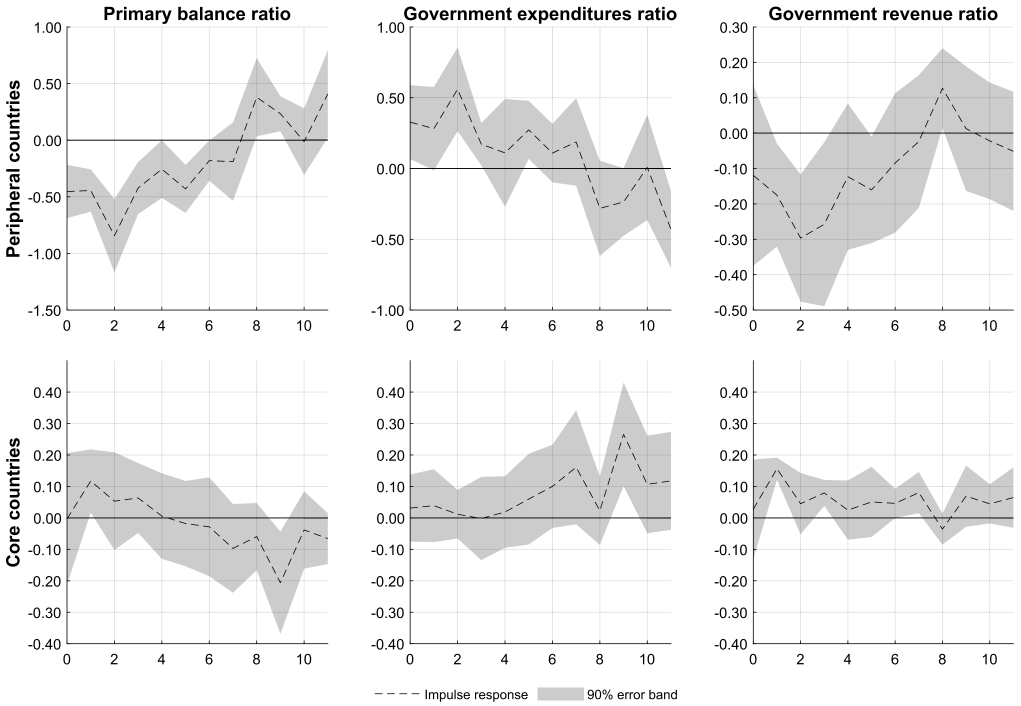
Fig. 8. Alternative unconventional monetary policy measures.

Table 1
Deviation of alternative macroprudential capital regulation shocks.

Variables	BL	A1	A2	A3	A4	A5	A6	A7
MPI cumulated	X	X	X	X	X	X	X	X
Basel gap	X		X	X	X	X	X	X
Lending spread	X	X	X	X	X	X	X	X
CLIFS	X	X	X	X	X	X	X	X
Nominal house prices in logs	X	X	X	X	X	X	X	X
Bank capital ratio	X	X	X	X	X	X	X	X
Bank-loans-to-GDP ratio		X						
MPIANN cumulated			X					
Real GDP in logs				X				
Bank stock price in logs					X			
Bank credit default swap						X		
Bank loans to total assets ratio							X	
Bank dom. gov. bond holdings ratio								X

Notes: Alternative panel VAR model specifications to derive macroprudential capital regulation shocks. "BL" denotes the baseline model. "A1-A7" denote the alternative specifications. Moreover, "MPI" is the macroprudential policy indicator based on implementation dates. "MPIANN" is an equivalent indicator derived on the basis of announcement dates. "Bank loans" are loans to private non-financial corporations and loans for house purchases.

banks' domestic government bond holdings ratio, that is, domestic government bond holdings relative to total assets. In addition, we also consider the announcement of macroprudential capital policy measures. So far, the exogenous macroprudential policy shock is derived from an indicator based on implementation dates as recorded in MaPPED, which, however, might suffer from the shortcoming that the implemented macroprudential interventions are announced in advance (Hristov et al., 2021). Thus, at the time of actual policy implementation, the economy as a whole might have already started to adjust to the mere announcement of a capital-based regulatory change. All in all, we end up with seven alternative models. They are summarized in Table 1 in which an "X" indicates that the variable of the corresponding row enters the VAR of the corresponding column.



Notes: Impulse responses to a principal component shock measuring a restrictive capital-based macroprudential policy innovation. The ratios are cyclically adjusted. Positive values of the cyclically adjusted primary balance ratio denote an improvement, negative values a deterioration. The variation in the ratios is measured in percentage points.

Fig. 9. Impulse responses to a principal component shock.

Again, every panel VAR model is estimated with Bayesian methods using a Normal-Wishart prior for the parameters. Inference is based on 10,000 draws from the corresponding posterior distribution. We extract the capital-based macroprudential policy shocks from the estimated models by calculating the mean of the shock series of the respective 10,000 draws.[22] In a next step, we derive the first principal component of the resulting seven structural macroprudential policy shocks. Since the correlation across the individual shocks is very high, the first principal component explains 95.9% of their variance. This component then serves as the indicator of the unsystematic component of macroprudential policy.[23]

Fig. 9 shows the reactions of the cyclically adjusted fiscal variables to the principal component shock. The impulse responses are very similar to those reported before.

Alternative model specifications Finally, we re-estimate baseline model (1) using alternative model specifications: lag orders of two and six, a linear trend as well as a linear and quadratic trend. The results are reported in Appendix D (Fig. 12), and are again similar to our baseline.

3.5. State-dependent impulse responses

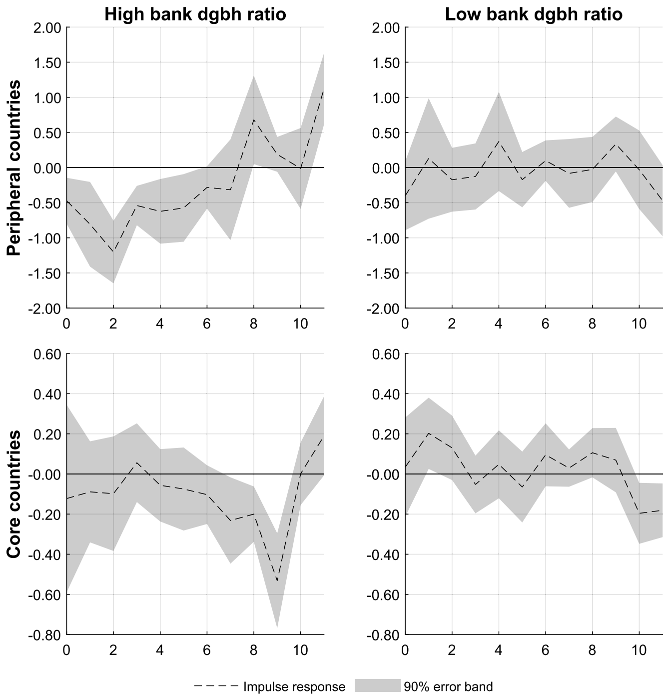
The impulse responses discussed so far display the average reactions of the cyclically adjusted fiscal ratios to capital-based macroprudential policy innovations. Thus, they are computed under the assumption that all variables equal their pooled mean, and that, accordingly, the interaction terms in equation (1) drop out.

In the following, we examine whether the dynamics of the fiscal response to macroprudential policy shocks depend on the state of the economy as reflected by the levels of the interaction variables. Particularly, we consider the level of the banks' domestic government bond holdings ratio as well as the government debt ratio in period $t-1$, the period preceding the shock. Thus, on the basis of (1), we compute the following conditional impulse response for every horizon $h = 0, 1, 2, ..., H$:

$$\frac{\partial X_{t+h}}{\partial \text{MPS}_t}|_{I_{v,t-1}=I_v^*, I_{-v,t-1}=\bar{I}_{-v}} = \theta_h + \zeta_h I_v^*, \tag{3}$$

[22] For the group of core countries, the shock series derived from alternative model A5 starts in 2006Q3, as credit default swaps for the Netherlands are only available from that date.

[23] We also estimated impulse responses of the fiscal variables to each of the seven individual shocks separately. The results are similar to the baseline.



Notes: State-dependent impulse responses of the cyclically adjusted primary balance ratio to a restrictive capital-based macroprudential policy shock. The responses are conditional on a high level of the banks' domestic government bond holdings ('dgbh') ratio and a low level, respectively, which are identified by one standard deviation above and below the pooled mean. Positive values of the cyclically adjusted primary balance ratio denote an improvement, negative values a deterioration. The variation in the primary balance ratio is measured in percentage points.

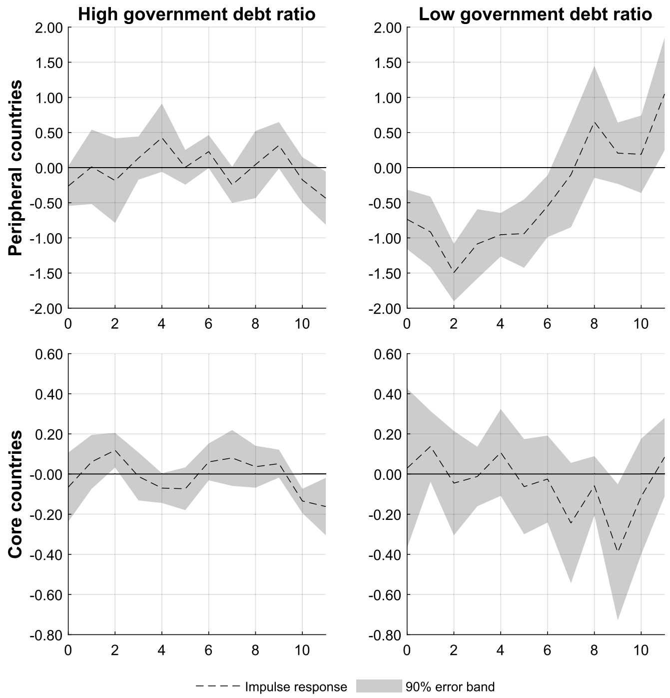
Fig. 10. Reaction of cyclically adjusted primary balance ratio conditional on banks' domestic government bond holdings ratio.

where we condition on the respective interaction variable $I_{v,t-1}$ taking the value I_v^*. The second interaction variable is assumed to equal its pooled mean, that is, $I_{-v,t-1} = \bar{I}_{-v}$. For each v, we consider a high and a low value of I_v^*, which are given by one standard deviation above and below the pooled mean, respectively.

Fig. 10 shows the impulse responses of the cyclically adjusted primary balance ratio to a sudden capital-based macroprudential policy tightening conditional on the level of the banks' domestic government bond holdings ratio. When this share and thus the nexus are already elevated, the worsening of the cyclically adjusted primary balance ratio in response to a restrictive shock to macroprudential capital regulation is comparatively strong. The result holds for both groups of countries, but the dynamics of the cyclically adjusted primary balance ratio again differ between the two groups. In peripheral countries, the drop in the cyclically adjusted primary balance ratio occurs immediately after the shock, while in core countries, the decline is delayed. By contrast, when banks' holdings of domestic government bonds are relatively low, the cyclically adjusted primary balance ratio barely reacts to the shock.

Furthermore, Fig. 11 displays the responses of the cyclically adjusted primary balance ratio to a capital-based macroprudential policy shock conditioned on the level of the government debt ratio. Empirical evidence suggests that the fiscal space is restricted when the government debt ratio is relatively high (Bohn, 1998; Ghosh et al., 2013). Particularly, the scope for a further debt increase might be limited, for example, by the disciplining effect of the capital markets. Our findings support this view for both country groups. The cyclically adjusted primary balance ratio barely worsens after the shock when the government debt ratio is already high. Accordingly, fiscal policy seems to follow a rather conservative path. By contrast, in peripheral countries, the cyclically adjusted primary balance ratio deteriorates after the shock when the government debt ratio is relatively low. This suggests that the additional scope for higher deficits following the macroprudential tightening is being used.

According to our results, macroprudential policy should be aware of the unintended side effects of a tightening in macroprudential capital regulation. Fiscal balances may deteriorate while the sovereign-bank nexus might intensify, possibly resulting in an increase in the risk to financial stability.



Notes:State-dependent impulse responses of the cyclically adjusted primary balance ratio to a restrictive capital-based macroprudential policy shock. The responses are conditional on a high level of the government debt ratio and a low level, respectively, which are identified by one standard deviation above and below the pooled mean. Positive values of the primary balance ratio denote an improvement, negative values a deterioration. The variation in the cyclically adjusted primary balance ratio is measured in percentage points.

Fig. 11. Reaction of cyclically adjusted primary balance ratio conditional on the government debt ratio.

4. Conclusion

We examine the fiscal footprint of macroprudential policy in euro area countries arising through the *bond market channel*, according to which policy affects the price at which government bonds sell (Reis, 2021). Particularly, we estimate local projections to generate impulse responses of the cyclically adjusted primary balance ratio to shocks that reflect an unexpected tightening in macroprudential capital regulation.

Our results suggest that in peripheral countries, the cyclically adjusted primary balance ratio deteriorates after a restrictive capital-based macroprudential shock. Moreover, banks in peripheral countries increase their domestic sovereign bond holdings after a sudden tightening in macroprudential capital regulation, which contributes to the lowering of the yield spread, that is, the difference between the yield on sovereign bonds and EURIBOR three-month rate. Hence, macroprudential policy leaves a fiscal footprint, which may amplify the negative effect of the sovereign-bank nexus to the extent that sovereign risk rises. By contrast, in core countries, the cyclically adjusted primary balance ratio barely deteriorates after a sudden tightening in macroprudential capital regulation. Furthermore, our findings suggest that in both groups of countries, the responses of the cyclically adjusted primary balance ratio to a capital-based macroprudential policy shock are state-dependent. The worsening of the ratio is more pronounced when banks' holdings of domestic government bonds is comparatively large. However, in peripheral countries, there might be a disciplining effect emanating from capital markets, that is, a relatively high government debt ratio seems to create incentives to avoid a deterioration of the primary balance following a restrictive capital-based macroprudential policy innovation.

CRediT authorship contribution statement

Nikolay Hristov: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing, Conceptualization, Formal analysis. **Oliver Hülsewig:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Benedikt Kolb:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Data

A.1. Baseline model

ECB Statistical Data Warehouse:

- Gross domestic product at market prices, chain linked volume
  MNA.Q.Y.XX.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.LR.N
- Government primary balance as % of GDP, deficit (-)/ surplus (+)
  GFS.Q.N.XX.W0.S13.S1._Z.B.B9P._Z._Z._Z.XDC_R_B1GQ._Z.S.V.N._T
- Government total expenditure as % of GDP
  GFS.Q.N.XX.W0.S13.S1.P.D.OTE._Z._Z._T.XDC_R_B1GQ._Z.S.V.N._T
- Government interest expenditure as % of GDP
  GFS.Q.N.XX.W0.S13.S1.C.D.D41._Z._Z._T.XDC_R_B1GQ._Z.S.V.N._T
- Government total revenue as % of GDP
  GFS.Q.N.XX.W0.S13.S1.P.C.OTR._Z._Z._Z.XDC_R_B1GQ._Z.S.V.N._T
- Government debt as % of GDP
  GFS.Q.N.XX.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T
- MFIs' holdings of domestic government bonds, outstanding amount (stock) in millions of euro, monthly frequency
  BSI.M.XX.N.A.A30.A.1.U6.2100.EUR.E
  This is converted to quarterly data using end-of-period monthly values.
- Total assets of a country's MFIs, outstanding amount (stock) in millions of euro, monthly frequency
  BSI.M.XX.N.A.T00.A.1.Z5.0000.Z01.E
  This is converted to quarterly data using end-of-period monthly values.
- EURIBOR 3-month rate
  FM.M.U2.EUR.RT.MM.EURIBOR3MD_.HSTA
  This is converted to quarterly data using monthly averages.
- Harmonized index of consumer prices
  ICP.M.XX.N.000000.4.INX
  This is converted to quarterly data using monthly averages.
- Sovereign composite indicator of systemic stress
  CISS.M.XX.Z0Z.4F.EC.SOV_CI.IDX
  This is converted to quarterly data using monthly averages.

In the series' codes XX is a placeholder for the country acronym: Austria (AT), Belgium (BE), Finland (FI), France (FR), Germany (DE), the Netherlands (NL), Ireland (IR), Italy (IT), Portugal (PT), and Spain (ES). All fiscal data are seasonally adjusted by means of the IRIS Macroeconomic Modelling Toolbox.

A.2. Panel VAR model

Bank of International Settlements:

- Basel credit-to-GDP gap:
  Q:XX:P:A:C
- Nominal house prices, index:
  Q:XX:N:628

ECB Statistical Data Warehouse:

- The lending rate is computed as the weighted average over the lending rates on NFC loans and loans for house purchase. The weights correspond to the respective share of NFC loans and loans for house purchase.
  1. Lending rate on loans to households for house purchase, new business, monthly frequency,
     MIR.M.XX.B.A2C.A.R.A.2250.EUR.N
  2. Lending rate on loans to NFCs, new business, monthly frequency,
     MIR.M.XX.B.A2A.A.R.A.2240.EUR.N

  These were converted to quarterly averages from monthly observations.

- Financial stress indicator
  CLIFS.M.XX._Z.4F.EC.CLIFS_CI.IDX
  This is converted to quarterly data using monthly averages
- Banks' capital and reserves (banks' equity), outstanding amount, monthly frequency, end-of-period stocks,
  BSI.M.XX.N.A.L60.X.1.Z5.0000.Z01.E
  This is converted to quarterly end-of-period values from monthly observations.

Capital-based macroprudential policy indicators:

- From Hristov et al. (2021).

A.3. Additional variables

ECB Statistical Data Warehouse:

- MFI loan volume corresponds to the sum of NFC loans and household loans for house purchase:
  1. MFI volume of loans to households for house purchase, monthly frequency, end-of-period stock,
     BSI.M.XX.N.A.A20.A.1.U6.2250.Z01.E
  2. MFI volume of loans non-financial corporations (NFCs), monthly frequency, end-of-period stock,
     BSI.M.XX.N.A.A20.A.1.U6.2240.Z01.E

  These were converted to quarterly end-of-period values from monthly data.
- Sovereign bond rate, monthly frequency,
  IRS.M.XX.L.L40.CI.0000.EUR.N.Z
  This is converted to quarterly data using monthly averages
- National central banks total assets, outstanding amounts at the end of the period (stocks), millions of euro, monthly frequency,
  BSI.M.XX.N.N.T00.A.1.Z5.0000.Z01.E
  This is converted to quarterly end-of-period values from monthly observations.

Refinitiv-Datastream:

- Stock market index, sectoral subindex for "Banks",
  BANKSXX
  This is converted to quarterly data using monthly averages.
- Credit default swaps, 5-year government bonds,
  XXG5EAC
  This is converted to quarterly data using monthly averages.

Shadow short rate:

- Leo Krippner's shadow short rate is taken from: https://www.ljkmfa.com/.

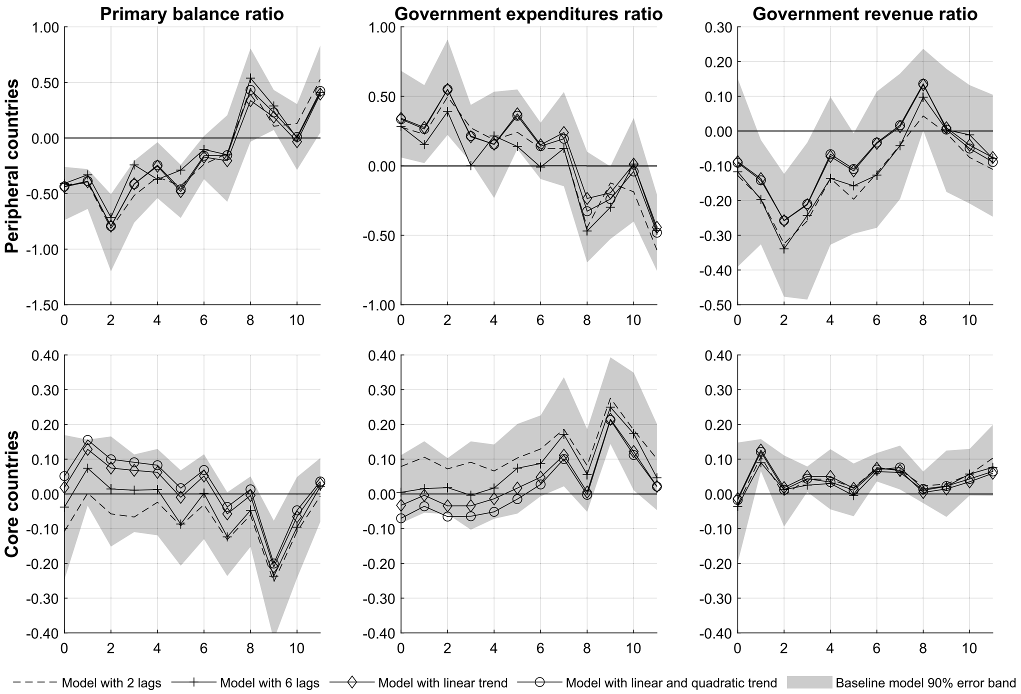
Appendix B. Panel VAR model set-up

For every element of the vector of endogenous variables $y_{i,t}$, we use a pooled set of $M \cdot T$ observations, where M denotes the number of countries and T the number of observations. For each cross-sectional unit, the error terms are assumed to be normally distributed with a homogeneous variance-covariance matrix Σ, that is $\varepsilon_{i,t} \sim \mathcal{N}(0, \Sigma)$. After stacking the $\varepsilon_{i,t}$ into a vector $\varepsilon_t = [\varepsilon'_{1,t} \ldots \varepsilon'_{M,t}]'$, we have $\varepsilon_t \sim \mathcal{N}(0, I_M \otimes \Sigma)$, where I_M is an identity matrix of dimension M.

Appendix C. Details on the MaPPED database

The MaPPED database by Budnik and Kleibl (2018) has been constructed by ECB experts and national authorities based on a survey. It features 1,925 policy actions in 27 EU countries and the UK for the sample 1995-2018. The database provides a detailed characterisation of each policy action, for example, whether it was a tightening, loosening, or ambiguous. Moreover, it includes the activation date of a measure, announcement date, and previous or subsequent adjustments. Relative to other macroprudential databases such as the IMF iMaPP, it contains more detailed information on each measure and a better coverage of euro area countries over our sample.

Appendix D. Alternative model specifications



Notes: Impulse responses to a restrictive capital-based macroprudential policy shock. The ratios are cyclically adjusted. Positive values of the cyclically adjusted primary balance ratio denote an improvement, negative values a deterioration. The variation in the ratios is measured in percentage points.

Fig. 12. Alternative model specifications.

References

Acharya, V., Drechsler, I., Schnabl, P., 2014a. A Pyrrhic Victory? Bank bailouts and sovereign credit risk. J. Finance 69, 2689–2739.

Acharya, V., Engle, R., Pierret, D., 2014b. Testing macroprudential stress tests: the risk of regulatory risk weights. J. Monet. Econ. 65, 36–53.

Acharya, V.V., Steffen, S., 2015. The "greatest" carry trade ever? Understanding eurozone bank risks. J. Financ. Econ. 115, 215–236.

Adrian, T., Boyarchenko, N., Giannone, D., 2019. Vulnerable growth. Am. Econ. Rev. 109, 1263–1289.

Adrian, T., Grinberg, F., Liang, N., Malik, S., Yu, J., 2022. The term structure of growth-at-risk. Am. Econ. J. Macroecon. 14, 283–323.

Aikman, D., Bridges, J., Hacioglu Hoke, S., O'Neill, C., Raja, A., 2021. Credit, capital and crises: a GDP-at-Risk approach. CEPR Discussion Papers 15864. C.E.P.R. Discussion Papers.

Akinci, O., Olmstead-Rumsey, J., 2018. How effective are macroprudential policies? An empirical investigation. J. Financ. Intermed. 33, 33–57.

Alam, Z., Alter, A., Eiseman, J., Gelos, R., Kang, H., Narita, M., Nier, E., Wang, N., 2019. Digging Deeper - Evidence on the Effects of Macroprudential Policies from a New Database. IMF Working Paper. International Monetary Fund.

Altavilla, C., Pagano, M., Simonelli, S., 2017. Bank exposures and sovereign stress transmission. Rev. Finance 21, 2103–2139.

Anand, K., Mankart, J., 2020. Sovereign risk and bank fragility. Discussion Papers 54/2020. Deutsche Bundesbank.

Angelini, P., Neri, S., Panetta, F., 2014. The interaction between capital requirements and monetary policy. J. Money Credit Bank. 46, 1073–1112.

Arslan, Y., Upper, C., 2017. Macroprudential frameworks: implementation and effectiveness. In: Bank for International Settlements (Ed.), Macroprudential Frameworks, Implementation and Relationship with Other Policies. In: BIS Papers, vol. 94. Bank for International Settlements, pp. 25–47.

Arslanalp, S., Tsuda, T., 2014. Tracking global demand for advanced economy sovereign debt. IMF Econ. Rev. 62, 430–464.

Battistini, N., Pagano, M., Simonelli, S., 2014. Systemic risk, sovereign yields and bank exposures in the euro crisis [Real effects of the sovereign debt crises in Europe: evidence from syndicated loans]. Econ. Policy 29, 203–251.

BCBS, 2017. The regulatory treatment of sovereign exposures. Technical Report December. Basel Committee on Banking Supervision.

Ben-David, I., Palvia, A.A., Stulz, R.M., 2019. Do Distressed Banks Really Gamble for Resurrection? NBER Working Papers 25794. National Bureau of Economic Research.

Benes, J., Kumhof, M., 2015. Risky bank lending and countercyclical capital buffers. J. Econ. Dyn. Control 58, 58–80.

Bidder, R., Krainer, J., Shapiro, A., 2021. De-leveraging or de-risking? How banks cope with loss. Rev. Econ. Dyn. 39, 100–127.

Boar, C., Gambacorta, L., Lombardo, G., da Silva, L.A.P., 2017. What are the effects of macroprudential policies on macroeconomic performance? BIS Q. Rev., 71–88.

Bohn, H., 1998. The behavior of U.S. public debt and deficits. Q. J. Econ. 113, 949–963.

Born, B., Müller, G., Pfeifer, J., Wellmann, S., 2020. Different No More: Country Spreads in Advanced and Emerging Economies. CESifo Working Paper Series 8083. CESifo.

Born, B., Müller, G.J., Pfeifer, J., Wellmann, S., 2018. Market Discipline? Sovereign Spreads. Fiscal Adjustments, and Political Turnover. mimeo.

Brandao-Marques, L., Chen, Q., Raddatz, C., Vandenbussche, J., Xie, P., 2022. The riskiness of credit allocation and financial stability. J. Financ. Intermed. 51.

Brunnermeier, M.K., Garicano, L., Lane, P.R., Pagano, M., Reis, R., Santos, T., Thesmar, D., Nieuwerburgh, S.V., Vayanos, D., 2016. The sovereign-bank diabolic loop and ESBies. Am. Econ. Rev. 106, 508–512.

Budnik, K., Kleibl, J., 2018. Macroprudential regulation in the European Union in 1995-2014: Introducing a new data set on policy actions of a macroprudential nature. Working Paper Series 2123. European Central Bank.

Budnik, K., Ruenstler, G., 2022. Identifying structural VARs from sparse narrative instruments: dynamic effects of US macroprudential policies. J. Appl. Econom.

Buser, S.A., Chen, A.H., Kane, E.J., 1981. Federal deposit insurance, regulatory policy, and optimal bank capital. J. Finance 36, 51–60.

Calem, P., Rob, R., 1999. The impact of capital-based regulation on bank risk-taking. J. Financ. Intermed. 8, 317–352.

Calomiris, C.W., Kahn, C.M., 1991. The role of demandable debt in structuring optimal banking arrangements. Am. Econ. Rev. 81, 497–513.

Cerutti, E., Correa, R., Fiorentino, E., Segalla, E., 2017. Changes in prudential policy instruments - a new cross-country database. Int. J. Cent. Bank. 13, 477–503.

Chari, V.V., Dovis, A., Kehoe, P.J., 2020. On the optimality of financial repression. J. Polit. Econ. 128, 710–739.

Cloyne, J.S., Jorda, O., Taylor, A.M., 2020. Decomposing the Fiscal Multiplier. NBER Working Papers 26939. National Bureau of Economic Research, Inc.

Crosignani, M., 2021. Bank capital, government bond holdings, and sovereign debt capacity. J. Financ. Econ. 141, 693–704.

Dell'Ariccia, G., Ferreira, C., Jenkinson, N., Laeven, L., Martin, A., Minoiu, C., Popov, A., 2018. Managing the sovereign-bank nexus. Working Paper Series 2177. European Central Bank.

Drechsler, I., Drechsel, T., Marques-Ibanez, D., Schnabl, P., 2016. Who borrows from the lender of last resort? J. Finance 71, 1933–1974.

Driscoll, J.C., Kraay, A.C., 1998. Consistent covariance matrix estimation with spatially dependent panel data. Rev. Econ. Stat. 80, 549–560.

Duprey, T., Klaus, B., Peltonen, T.A., 2015. Dating systemic financial stress episodes in the EU countries. Working Paper Series 1873. European Central Bank.

Duprey, T., Ueberfeldt, A., 2020. Managing GDP Tail Risk. Staff Working Papers 20-3. Bank of Canada.

ECB, 2022. Financial Stability Review, November 2022. European Central Bank.

Edge, R.M., Liang, J.N., 2022. Financial stability committees and the Basel III countercyclical capital buffer. Int. J. Cent. Bank. 18, 247–299.

Eickmeier, S., Kolb, B., Prieto, E., 2018. Macroeconomic effects of bank capital regulation. Discussion Papers 44/2018. Deutsche Bundesbank.

ESRB, 2019. A Review of Macroprudential Policy in the EU in 2018. European Systemic. Risk Board.

ESRB, 2021a. Report on the Financial Stability Implications of Support Measures to Protect the Real Economy from the COVID-19 Pandemic, Feb. 2021. European Systemic Risk Board.

ESRB, 2021b. A Review of Macroprudential Policy in the EU in 2020. European Systemic Risk Board.

ESRB, 2022. Annual Report 2021. European Systemic Risk Board.

Farhi, E., Tirole, J., 2018. Deadly embrace: sovereign and financial balance sheets doom loops. Rev. Econ. Stud. 85, 1781–1823.

Figueres, J.M., Jarocinski, M., 2020. Vulnerable growth in the euro area: measuring the financial conditions. Econ. Lett. 191, 109126.

Franta, M., Gambacorta, L., 2020. On the effects of macroprudential policies on growth-at-risk. Econ. Lett. 196, 109501.

Galan, J.E., 2020. The benefits are at the tail: uncovering the impact of macroprudential policy on growth-at-risk. J. Financ. Stab. 100831.

Galati, G., Moessner, R., 2018. What do we know about the effects of macroprudential policy? Economica 85, 735–770.

Ghosh, A.R., Kim, J.I., Mendoza, E.G., Ostry, J.D., Qureshi, M.S., 2013. Fiscal fatigue, fiscal space and debt sustainability in advanced economies. Econ. J., 4–30.

de Groot, O., Holm-Hadulla, F., Leiner-Killinger, N., 2015. Cost of borrowing shocks and fiscal adjustment. J. Int. Money Financ. 59, 23–48.

Gropp, R., Mosk, T., Ongena, S., Wix, C., 2019. Banks response to higher capital requirements: evidence from a quasi-natural experiment. Rev. Financ. Stud. 32, 266–299.

Hardouvelis, G., Vayanos, D., 2023. The Greek Economic Crisis and the Banks. GreeSE – Hellenic Observatory Papers on Greece and Southeast Europe 180. Hellenic Observatory, LSE.

Heid, F., Porath, D., Stolz, S., 2004. Does capital regulation matter for bank behaviour? Evidence for German savings banks. Discussion Paper Series 2: Banking and Financial Studies 2004, 03. Deutsche Bundesbank, 2004.

Holló, D., Kremer, M., Lo Duca, M., 2012. CISS - a composite indicator of systemic stress in the financial system. Working Paper Series 1426. European Central Bank.

Hristov, N., Hülsewig, O., Kolb, B., 2021. Macroprudential policy and the sovereign-bank nexus in the euro area. Discussion Papers 32/2021. Deutsche Bundesbank.

Hülsewig, O., Rottmann, H., 2022. Euro area Periphery Countries' fiscal policy and monetary policy surprises. Oxf. Bull. Econ. Stat. 84, 544–568.

IMF, 2014. Global Financial Stability Report October 2014. International Monetary Fund, New York.

IMF, 2018. Global Financial Stability Report October 2018. International Monetary Fund, New York.

Jokipii, T., Milne, A., 2011. Bank capital buffer and risk adjustment decisions. J. Financ. Stab. 7, 165–178.

Jordà, Ò., 2005. Estimation and inference of impulse responses by local projections. Am. Econ. Rev. 95, 161–182.

Krippner, L., 2013. Measuring the stance of monetary policy in zero lower bound environments. Econ. Lett. 118, 135–138.

Kuttner, K.N., Shim, I., 2016. Can non-interest rate policies stabilize housing markets? Evidence from a panel of 57 economies. J. Financ. Stab. 26, 31–44.

Lang, J.H., Rusnák, M., Greiwe, M., 2023. Medium-term growth-at-risk in the euro area. Working Paper Series 2808. European Central Bank.

Legrenzi, G., Milas, C., 2013. Modelling the fiscal reaction functions of the GIPS based on state-varying thresholds. Econ. Lett. 121, 384–389.

Marcus, A.J., 1984. Deregulation and bank financial policy. J. Bank. Finance 8, 557–565.

Mendicino, C., Nikolov, K., Suarez, J., Supera, D., 2020. Bank capital in the short and in the long run. J. Monet. Econ. 115, 64–79.

Mourre, G., Poissonnier, A., 2019. What drives the responsiveness of the budget balance to the business cycle in EU countries? Intereconomics: Rev. Eur. Econ. Policy 54, 237–249.

Mourre, G., Poissonnier, A., Lausegger, M., 2019. The Semi-Elasticities Underlying the Cyclically-Adjusted Budget Balance: an Update and Further Analysis. European Economy Discussion Papers 098. Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.

Ohls, J., 2017. Moral suasion in regional government bond markets. Discussion Papers 33/2017. Deutsche Bundesbank.

Ongena, S., Popov, A., Horen, N.V., 2019. The invisible hand of the government: moral suasion during the European sovereign debt crisis. Am. Econ. J. Macroecon. 11, 346–379.

Peydro, J.L., Polo, A., Sette, E., 2021. Monetary policy at work: security and credit application registers evidence. J. Financ. Econ. 140, 789–814.

Ramey, V.A., Zubairy, S., 2018. Government spending multipliers in good times and in bad: evidence from US historical data. J. Polit. Econ. 126, 850–901.

Reis, R., 2021. The fiscal footprint of macroprudential policy. In: Pasten, E., Reis, R. (Eds.), Independence, Credibility, and Communication of Central Banking. Banco Central de Chile, Santiago, Chile, pp. 133–171.

Rime, B., 2001. Capital requirements and bank behaviour: empirical evidence for Switzerland. J. Bank. Finance 25, 789–805.

Shrieves, R.E., Dahl, D., 1992. The relationship between risk and capital in commercial banks. J. Bank. Finance 16, 439–457.

Tenreyro, S., Thwaites, G., 2016. Pushing on a string: US monetary policy is less powerful in recessions. Am. Econ. J. Macroecon. 8, 43–74.

Theofilakou, N., Stournaras, Y., 2012. Government solvency and financial markets: dynamic panel estimates for the European Monetary Union. Econ. Lett. 115, 130–133.