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Abstract

We explore how changes in capital-based macroprudential regulation in the euro area affect the exposure of national banking sectors to domestic government debt, thus strengthening or weakening the sovereign-bank nexus. To do so, we construct a measure of macroprudential policy based on the Macroprudential Policy Evaluation Database (MaPPED) and estimate responses to the *unsystematic* component of macroprudential policy in panel vector autoregressive models for euro area ”core” and ”periphery” countries. Our main finding suggests that an unsystematic capital-based macroprudential policy tightening increases banks' exposure to domestic sovereign bonds in the periphery countries and thus deepens the sovereign-bank nexus. By contrast, banks in the core countries expand their loan portfolios, rather than adjusting their domestic sovereign bond holdings, in response to the shock. We show that this result can be tied to the theoretical literature and investigate several transmission channels. Our results are highly robust to changes in the econometric set-up and the macroprudential indicator used.

JEL-Codes: C330, G210, G280, H630.

Keywords: macroprudential policy, euro area, sovereign-bank nexus, panel vector autoregressive model.

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1 Introduction

The euro area banking sector has proved resilient in the course of the COVID-19 crisis. In particular, banks managed to support the economy through continued lending, including to the sectors most affected by the lockdown measures (ESRB, 2021). Thus, they played a different role than they did past crisis periods, mainly thanks to macroprudential policies that strengthened the regulatory standards. Indeed, the global financial crisis of 2007-2008 highlighted the importance of a holistic macroprudential approach to financial regulation aimed at increasing the shock-absorption capacity and counteracting the build-up of systemic risk in the financial system. In the meantime, numerous countries have put substantial efforts into refining and strengthening their macroprudential policy frameworks (IMF, 2018). The latter comprise capital and leverage regulation of banks and other financial institutions, various borrowing limits like caps on loan-to-value or debt-to-income ratios, liquidity and reserve requirements. Even though the experience with this type of policy is rather limited and an academic consensus about its transmission and effectiveness has not yet been reached, several theoretical and empirical studies suggest that various macroprudential tools do indeed contribute to achieving certain financial stability objectives.[1]

However, concerns have been raised that capital-based macroprudential instruments, i.e. those related to the capital regulation of banks, might have the unintended side effect of intensifying the interconnectedness between banks and their sovereigns – the so called *sovereign-bank nexus*. This might potentially undermine financial stability (Basel Committee on Banking Supervision (BCBS), 2017; IMF, 2014, 2018; Altavilla et al., 2017). In this paper, we investigate the presence of such an effect of capital-based macroprudential policies from a macro perspective for the euro area.

The aforementioned concerns regarding potential side effects of the capital regulation mainly reflect the fact that the existing regulatory framework includes several instruments which – although primarily targeting other financial stability aspects – might potentially affect banks' incentives to hold domestic sovereign bonds or certain foreign public bonds denominated in domestic currency (Acharya et al., 2014b; BCBS, 2017).[2] In particular, such bonds receive a relatively more favourable treatment, as they are typically assigned a risk weight of zero in the calculation of risk-weighted assets. This enables banks to increase their government bond portfolios without raising their Tier 1 capital, which is an example of *regulatory arbitrage* (Acharya and Steffen, 2015). The euro area represents a special case here as the aforementioned relative advantages apply symmetrically to the sovereign bonds issued by any member state of the euro area. Despite this symmetry, however, euro area banks' government bond portfolios exhibit a substantial home bias.[3]

[1] See for example Claessens (2015), Cerutti et al. (2017a) and Galati and Moessner (2018) for literature surveys.

[2] See BCBS (2017) and ESRB (2019) for a detailed description of the legal framework and the way it might affect banks' sovereign debt holdings. See Alogoskoufis and Langfield (2019) for a theoretical rationale.

[3] For potential reasons for the home bias, see Section 2.

Given the favourable regulatory treatment of public debt and the apparent home-bias tendencies among banks, a tightening of the requirements on risk-weighted capital might be associated with banks tilting their asset portfolios more heavily towards domestic government bonds, thus contributing to the sovereign-bank nexus. The latter is widely viewed as one of the most important amplifiers of the European debt crisis in 2010-2012 as it gave rise to "doom loops" of mutually reinforcing deteriorations in the sovereign's creditworthiness and the solidity of the domestic banking sector (Acharya et al., 2014a; Brunnermeier et al., 2016; Farhi and Tirole, 2018; Dell'Ariccia et al., 2018). Given the enduring substantial exposure of euro area banks to domestic government securities, the sovereign-bank nexus is still viewed as a major challenge to financial stability in the European Monetary Union (EMU) and beyond, which has even been reinforced recently by the COVID-19-related surge in public debt (ESRB, 2019; IMF, 2019; ECB, 2020).

Against this background, we quantitatively investigate, using a sample of euro area countries, how changes in *capital-based* macroprudential instruments affect the exposure of national banking sectors to domestic government debt, thus strengthening or weakening the sovereign-bank nexus. *Capital-based* policy measures are those regulating financial institutions' various capital and leverage ratios, loan-loss provisioning as well as risk weights assigned to the different asset classes. Formally, we estimate panel vector autoregressive (VAR) models using Bayesian methods and analyze the adjustment of domestic sovereign debt portfolios undertaken by euro area banks in response to shocks reflecting changes in the *unsystematic/exogenous* component of *capital-based* macroprudential regulation. To capture such changes we derive macroprudential policy indices based on the Macroprudential Policy Evaluation Database (MaPPED developed by Budnik and Kleibl (2018) in cooperation with national authorities. This database contains detailed information on the measures implemented in the member states of the European Union (EU). We account for possible cross-country heterogeneity stemming, for example, from differences in economic structures and developments undergone during the European debt crisis, by considering two country groups separately: Austria, Belgium, Finland, France, Germany and the Netherlands make up the *core countries*, while the group of *periphery countries* consists of Spain, Italy, Portugal and Ireland.

Our main findings are as follows. Changes in the *unsystematic* component of capital-based macroprudential policy have a statistically significant and persistent effect on banks' exposure to domestic sovereign bonds. However, there is a noticeable dichotomy between the periphery and the core economies of the euro area. In the former group of countries, the banking sector reacts to an unsystematic macroprudential tightening by strongly increasing the balance sheet share of domestic public debt while at the same time scaling down the share of loans to the non-financial private sector. The core countries, by contrast, show the opposite reactions. Overall, *unsystematic* shifts in capital-based regulation tend to strengthen the sovereign-bank nexus in the periphery of the EMU but weaken it in the core. We discuss theoretical rationales for these results, relying on the *moral hazard* theory of banks' portfolio selection as well as the *capital buffer* theory of banking. Clearly, our analysis does not represent an evaluation of the overall effectiveness of capital-based

macroprudential policy. In fact, in this paper we also document that the latter successfully contributes towards increasing the loss-absorption capacity of banks for any given shock size. Our main findings merely show that in parts of the EMU, shifts in the unsystematic part of capital-based policy might increase banks' exposure to a certain type of risks which may or may not materialize in the future.

The main contribution of our paper is twofold. First, to the best of our knowledge, we are the first to explore the effects of macroprudential policy shocks on the sovereign-bank nexus from an explicitly macroeconomic perspective. This allows us to capture important aggregate-level interlinkages between banks' behavior and the rest of the economy. In contrast, as we explain below, the closely related contributions by Acharya et al. (2014b), Acharya and Steffen (2015), Bonner (2016) and Gropp et al. (2019), which also deal with the relationship between macroprudential regulation and the nexus, are microeconometric in nature. They resort to bank-level data and difference-in-difference techniques, thus being powerful in capturing partial-equilibrium, but not macroeconomic aspects. Second, unlike Acharya et al. (2014b) and Gropp et al. (2019), who derive their conclusions by looking at the effects of a single event – i.e. the change in capital requirements resulting from the stress test conducted by the European Banking Authority (EBA) in 2011 –, we explore the average effects of various macroprudential measures in the euro area over the period 1999-2018.

The paper is organized as follows. Section 2 gives an overview of the related literature. In Section 3, we discuss our benchmark panel VAR model set-up, the strategy to identify the unsystematic component of capital-based macroprudential policy and the data. Section 4 describes the construction of the macroprudential policy indicator. In Section 5, we present our main results and discuss possible theoretical rationales. Various robustness checks are then performed in Section 6. Lastly, Section 7 provides concluding remarks.

2 Related literature

Our paper is related to several strands of the literature. First, a number of empirical studies explore the determinants of the sovereign-bank nexus.[4] However, unlike our paper, these contributions focus on the effects of sovereign stress, monetary policy actions, public ownership and bail-outs as well as individual bank characteristics, while leaving macroprudential policy measures aside. Second, various studies empirically examine the effectiveness of different types of macroprudential instruments and their channels of transmission.[5] The findings provide insights into how credit growth, real output, private con-

[4]See Acharya et al. (2014a), Battistini et al. (2014), Brutti and Sauré (2015), Drechsler et al. (2016), Ongena et al. (2019), Peydro et al. (2017), Crosignani et al. (2020), Altavilla et al. (2017), Dell'Ariccia et al. (2018), Carpinelli and Crosignani (forthcoming) and Hristov et al. (2021), among others.

[5]See Bakker et al. (2012), Maddaloni and Peydro (2013), Crowe et al. (2013), Claessens et al. (2013), Vandenbussche et al. (2015), Cerutti et al. (2017a), Kuttner and Shim (2016), Bruno et al. (2017), Akinci and Olmstead-Rumsey (2018), Richter et al. (2018), Cizel et al. (2019), Acharya et al. (2014b), Bridges et al. (2014), Jimenez et al. (2017), or Acharya et al. (2020). VanHoose (2007, 2008), Claessens (2015) and Galati and Moessner (2018) provide comprehensive literature surveys. One main finding of this

sumption and house prices are affected by macroprudential policy measures. However, banks' portfolio adjustments strengthening the bank-sovereign nexus are – to the best of our knowledge – not analyzed.

Our work is most closely related to the contributions by Acharya et al. (2014b), Acharya and Steffen (2015), Bonner (2016) and Gropp et al. (2019). Acharya et al. (2014b) analyse the results of the stress tests imposed by the European Banking Authority (EBA) on the large European banks in 2011 by considering the efficacy of regulatory risk weights. They conclude that the way the weights are assigned have left financial sectors undercapitalized, and have provided perverse incentives to build up exposures to low-risk-weight assets such as domestic sovereign bonds. Focusing on the Netherlands, Bonner (2016) uses unique transaction-level data. His results show that the revision of regulations regarding liquidity and capital requirements in 2011 caused Dutch banks to increase their demand for government bonds beyond their internal risk management targets, while reducing their holdings of other bonds. Acharya and Steffen (2015) resort to detailed bank-level data for European countries in the period 2010-2012. They show that undercapitalized banks – i.e. those with a relatively low Tier 1 capital ratio – had a stronger incentive, relative to their better capitalized counterparts, to increase their return on equity by investing in government bonds issued by the euro area periphery countries, i.e. Greece, Ireland, Portugal, Spain and Italy, as these bonds offered high yields but were subject to zero regulatory risk weights. The findings indicate the presence of regulatory capital arbitrage, thereby underscoring the link between financial regulation and banks' demand for sovereign debt. Gropp et al. (2019) also focus on the EBA stress tests in 2011 and use a diff-in-diff approach to investigate the effects of the resulting capital requirements. They find that banks confronted with higher capital requirements increased their sovereign exposures relative to other banks. We differ from these papers by taking a purely macroeconomic perspective. Moreover, we explore the average effects of a broad set of capital-based macroprudential policy measures over a longer period, instead of focusing on a particular episode such as the EBA exercise.

From a methodological perspective, our paper is also related to several studies using similar econometric techniques or data to analyse the transmission of macroprudential policy. A variety of recent papers employ time-series models to assess the macroeconomic effects of shocks to banks' capital ratios (Berrospide and Edge, 2010; Noss and Toffano, 2016; Behn at al., 2016; Gross et al., 2016; Meeks, 2017; Eickmeier et al. 2018; Kanngiesser et al., 2017 and 2020). To capture the shock, these studies mostly use the observable actual capital ratio.[6] While they employ different shock identification schemes and apply the analysis to different geographical units, the majority of these papers find that a shock

literature strand is that borrower-based instruments, tightenings in reserve requirements and capital-inflow management seem to be effective in decelerating credit growth and the expansion of house prices. In contrast, the theoretical predictions as well as the empirical evidence regarding capital-based measures are substantially more mixed.

[6]Exceptions are Kanngiesser et al. (2020), who resort to the buffer relative to an estimated target ratio, and Meeks (2017), where the microprudential regulatory capital requirements are used. Eickmeier et al. (2018) employ a narrative approach for the US

pushing the actual or regulatory capital ratio upwards, or the buffer downwards, is associated with a significant decline of lending growth and GDP in the short run.[7] Unlike our paper, however, all these studies are silent about possible effects of the shock on banks' exposure to domestic sovereign debt. Furthermore, apart from Meeks (2017) for the UK, the aforementioned contributions do not resort to an explicit measure of prudential policy. Accordingly, as also acknowledged in the papers, the identified capital ratio shock should be viewed more as a specific credit supply shock which reflects not only unsystematic policy shifts but also unexpected gains or losses in banks' loan and trading books. In contrast, we employ an explicit indicator of capital-based macroprudential policy. Also related to our analysis are Kim and Mehrotra (2017, 2018, 2019) who estimate structural panel VAR models with macroeconomic data for different country groups covering. They find that unsystematic adjustments of macroprudential measures induce a persistent drop in real output, consumer prices, aggregate investment and nominal credit.[8] Similar results for the US are obtained by Budnik and Ruenstler (2020), who identify shocks to macroprudential policy by means of proxy VARs. Bachmann and Rueth (2020) use a SVAR model for the US and report that unexpected tightenings in loan-to-value ratios lead to a decline in real output and business investments while the response of residential investment depends on the systematic response of monetary policy.[9] Moreover, Poghosyan (2020) and Budnik (2020) resort to the same macroprudential database as we do. Based on cross-country panel regressions for the EU28, these papers investigate the effects of various policy measures on real credit, real estate prices and private consumption.

Finally, several contributions propose reasons other than macroprudential regulation for the lack of cross-country diversification of sovereign risk in the euro area's banking system. First, regulatory policy is not the sole driver of banks' demand for public debt. The latter is held by financial institutions for the purpose of liquidity management and also as a source of collateral and returns (Dell'Ariccia et al. 2018). Furthermore, banks might be subject to *moral suasion*, i.e. government pressure on banks towards a higher investment in domestic public debt (Dell'Ariccia et al., 2018; Ongena et al., 2019; Becker and Ivashina, 2018). Moreover, banks are often not rewarded for holding a balanced sovereign portfolio as rating agencies tend not to rate them above their sovereign in any case (Bilbiie et al., 2020). Several papers have also shown that particular monetary policy interventions might incentivize banks in some euro area countries to hold more domestic public debt (for example Acharya and Steffen, 2015; Carpinelli and Crosignani, forthcoming; Hristov et al., 2021), e.g. by reinforcing the tendency towards *gambling for resurrection* (Drechsler et al., 2016).

[7] Exceptions are Berrospide and Edge (2010), who find the opposite for the US and Gross et al. (2016), where three different types of capital-ratio shocks are considered, each leading to different responses of lending and real activity.

[8] Kim and Mehrotra resort to the macroprudential policy database constructed by Cerutti et al. (2017b).

[9] Bachmann and Rueth (2020) refer to survey data from the Federal Housing Finance Agency in the US to measure loan-to-value ratios.

3 Methodology and data

3.1 Empirical model

We use a panel VAR model in reduced form:

$$y_{k,t} = \sum_{j=1}^{p} B_j y_{k,t-j} + c_k + \varepsilon_{k,t}, \tag{3.1}$$

where $y_{k,t}$ is a vector of endogenous variables for country k, B_j is a matrix of autoregressive coefficients for lag j, p is the number of lags, c_k is a vector of country-specific intercepts, which account for possible heterogeneity across the units, and $\varepsilon_{k,t}$ is a vector of reduced-form residuals. We refer to a policymakers' macroprudential reaction function regarding the selection of the endogenous variables. Specifically, our baseline model includes five variables: an indicator of *capital-based* macroprudential policy measures, the credit-to-GDP gap, a lending spread, an indicator of financial stress, and the share of domestic government bonds in banks' total assets. Our variable selection is based on Benes and Kumhof (2015), Angelini et al. (2014) and Boar et al. (2017), among others, who assume that macroprudential policy pursues the aim of attenuating the credit cycle. Moreover, since our main interest is in the effect of unsystematic/exogenous changes in capital-based macroprudential policy on banks' domestic government bond share, the domestic government bonds ratio serves as a direct indicator of the interconnectedness between the domestic banking sector and the corresponding sovereign. For every element of $y_{k,t}$, 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 reduced-form residuals are assumed to be normally distributed with a homogeneous variance-covariance matrix Σ, i.e. $\varepsilon_{k,t} \sim \mathcal{N}(0, \Sigma)$. After stacking the $\varepsilon_{k,t}$ into a vector $\varepsilon_t = [\varepsilon'_{1,t} \dots \varepsilon'_{M,t}]'$, we have $\varepsilon_t \sim \mathcal{N}(0, I_M \otimes \Sigma)$, where I_M is an identity matrix of dimension M.

Since our sample is short, we follow Ciccarelli et al. (2015) by adopting panel techniques. We consider two country groups, i.e. the *periphery countries* Italy, Spain, Portugal and Ireland, and the *core countries* comprising Austria, Belgium, Finland, France, Germany and the Netherlands.[10] The panel approach allows us to pool the diverse information from the two country groups, while controlling for heterogeneity across the units by considering country-specific fixed effects. One main advantage of this approach is that it increases the efficiency of the statistical inference.

Moreover, the grouping allows us to trace the effects of macroprudential policies in two regions with heterogeneous macroeconomic developments during the last two decades. In estimating separate panel VAR models for the two groups, we allow for possible structural heterogeneities across the groups. Such heterogeneities appear a priori very likely given the differences between the groups in terms of historical experience before the global fi-

[10]Note that we exclude Greece from our analysis, because the country was severely affected by the European sovereign debt crisis and obtained external finance only through financial aid programs from May 2010 onwards.

nancial crisis as well as during the European sovereign debt crisis, which arose between 2010 and 2013. All countries in the euro area fell into recession as a result of the global financial crisis. However, in the periphery countries the economic slack was more pronounced, because of a substantial loss of international price competitiveness and a strong increase in private and/or public debt that occurred before 2009. Furthermore, in the period 2010-2013 periphery countries' sovereigns faced difficulties in tapping international capital markets, leading to extraordinary fiscal distress. As explained in the introduction, the unfavorable situation was likely exaggerated by the emergence of *doom loops* due to the sovereign-bank nexus. As a consequence, Italy, Spain, Portugal and Ireland were forced to adopt substantial cyclical and structural adjustments in fiscal policy and start launching far-reaching structural reforms in labor and good markets. In contrast, during the European debt crisis, the core countries faced comparatively moderate recessions, benefited form their *safe-haven* status and were not forced to undertake noteworthy structural adjustments.

3.2 Data

The credit-to-GDP gap is provided by the Bank for International Settlements (BIS), and therefore also referred to as the *"Basel gap"*. It is defined as the trend deviation of the ratio of total credit to the non-financial private sector to GDP. The trend is obtained with a *one-sided* Hodrick-Prescott filter with a smoothing parameter of 400000. Positive Basel gap values can be interpreted as indicating an excessive, potentially unsustainable, credit expansion which is a frequent precursor of crises. Drehmann et al. (2011), Gourinchas and Obstfeld (2012), Jorda et al. (2013), and Drehmann and Juselius (2014) document the quite satisfactory properties of the credit-to-GDP gap as a financial crisis predictor. The gap is an integral part of policy-makers' decisions regarding adjustments of the countercyclcical capital buffer (CCyB) and is explicitly incorporated into the CCyB legislation in many euro area countries (BCBS, 2010).

The remaining macroeconomic data are taken from the ECB's Statistical Data Warehouse and collected on a quarterly basis.[11] 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 the loan rate on mortgage loans. The Country-Level Index of Financial Stress (CLIFS) is used as an indicator of financial market tensions or financial stress. Finally, we consider the share of several positions on the balance sheets of monetary financial institutes (MFIs), such as domestic government bond holdings, total loans as well as foreign government bond holdings, respectively, to total assets.[12] The macroprudential policy indicator (MPI) is derived from the Macroprudential Policy Evaluation Database – in Section 4, we provide a detailed description of the database and the construction of the indicator.

[11] See the Appendix A for a description of the data.

[12] In the following, we use the terms "MFIs" and "banks" interchangeably for simplicity.

The series are transformed from monthly to quarterly frequency where necessary. Since the implementation of macroprudential policy measures was substantially more limited before 2005 and the macroprudential database does not extend beyond the end of 2018, we consider the period from 2005Q1 to 2018Q4. In the robustness section, we estimate our model over the entire euro area period, i.e. 1999 to 2018, as well as over the post-crisis period only, i.e. 2007 to 2018.

3.3 Identification of the unsystematic component of macroprudential policy: Structural policy shocks

We estimate the VAR model (3.1) with Bayesian methods using a Normal-Wishart prior for the parameters. Inference is based on 10,000 draws from the corresponding posterior distribution. We set the lag order to four, i.e. $p = 4$, which accounts for possible delays in the interaction between the macroeconomic variables and macroprudential policy.[13] Based on the outcome of the estimated model, we generate impulse responses of the variables to the structural shocks $\eta_t = [\eta'_{1,t} \dots \eta'_{M,t}]'$, where $\eta_{k,t} \sim \mathcal{N}(0, I_N)$ and $\eta_t \sim \mathcal{N}(0, I_{N \cdot M})$. The relationship between $\eta_{k,t}$ and the reduced-form residuals is governed by $\varepsilon_{k,t} = A_0 \eta_{k,t}$, which holds for each cross-sectional unit $k = \{1, ..., M\}$ and $\Sigma = A_0 A'_0$.

We identify a structural shock related to macroprudential policy by imposing a recursive ordering upon $y_{k,t}$. This is implemented by assuming that the matrix A_0 corresponds to the lower triangular element in the Choleski factorization of the variance-covariance matrix Σ of ε_t. The MPI is ordered *first* and the corresponding orthogonal disturbance is interpreted as capturing the unsystematic/exogenous component of macroprudential policy. The ordering implies that the latter only reacts 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 rather slow-moving. In particular, the adjustment of macroprudential instruments suffers from a substantial inaction bias and sizable implementation lags. Various factors contribute to this delayed responsiveness: political-economy constraints, as the costs of prudential interventions are felt immediately, while the potential benefits only appear in the long run (Arslan and Upper, 2017) and as the final objective - *financial stability* - is barely quantifiable while the available tools to proxy the financial cycle or systemic risk are still underdeveloped (see e.g. Lim et al., 2011, Knot, 2014; Arslan and Upper, 2017; Dagher, 2018; Edge and Liang, 2020a,b). Moreover, in many countries multiple institutions are simultaneously responsible for prudential regulation, which might protract the decision-making process, in particular if the responsible bodies meet only infrequently (Edge and Liang, 2020a,b). Finally, the adjustment of many macroprudential instruments, especially those of the capital-based type, are preceded by a phase-in period of several quarters. Nevertheless, in Section 6.3, we check the robustness of our results to alternative Choleski orderings, thus allowing macroprudential policy to react on impact to more or

[13] Note that our results are robust to using lag lengths of between 2 and 6, see below.

even all of the shocks hitting the system. Before we present the results of our analysis, we discuss the construction of the MPI in detail.

4 Macroprudential policy indicator

4.1 Macroprudential policy database

We resort to the Macroprudential Policy Evaluation Database (MaPPED) provided by Budnik and Kleibl (2018) to measure changes in macroprudential policy. The database is constructed by experts in charge of prudential oversight and regulation at the ECB and national authorities. It comprises information on 1,925 policy actions in the 27 member states of the European Union, as well as in the United Kingdom. Relative to other macroprudential databases, MaPPED has the advantage that each policy action is given a very detailed description, the latter being represented by a finite set of items and subitems which are the same across policy actions and countries. Of particular importance is that for each macroprudential measure, MaPPED tracks the full set of corresponding policy changes over time, i.e. the dates of announcement, actual implementation, subsequent upward or downward adjustments and (potentially) deactivation. Several existing macroprudential databases, while having the clear advantage of covering a broader set of emerging and advanced economies, either contain only the date a measure entered into force but are silent about announcements, and subsequent tightenings or loosenings, or only allow for a less detailed and in some cases an arguably more subjective categorization of each measure.[14] The most recent versions of the Integrated Macroprudential Policy (iMaPP) database collected by Alam et al. (2019) also provides a relatively detailed categorization of the individual measures included. However, regarding the EMU countries we consider, the number of capital-based policy interventions in the period before 2013 contained in iMaPP is much smaller than in MaPPED. As capital-based policy is the main focus of our analysis, we refer in our baseline specification to MaPPED while resorting to iMaPP in a robustness check. Our results are qualitatively unaffected by the choice of macroprudential database.

Table 1 presents some descriptive summary statistics from MaPPED for the euro area countries in our sample. The numbers refer only to those policy changes characterized as *"legally binding"*. Interventions described as mere *"recommendation or guidance"* are excluded, since, in our view, they are less likely to induce changes in economic behavior. The table further covers only policy actions classified as either *"tightening"* or *"loosening"*. The remaining actions – described as *"unspecified or with an ambiguous impact"* – are discarded since they are not treated as policy changes in our empirical analysis (see Section 4.2).

Regarding our two country groups, i.e. *core* and *periphery*, we classify the different

[14] See the macroprudential databases used by Lim et al. (2011), Kuttner and Shim (2016), Cerutti et al. (2017b) as an example.

types of policy changes into four broader categories. *"Capital based"* covers the policy changes (1) to (4) which are directly related to the balance sheets of financial institutions (predominantly banks). *"Borrower based"*, corresponding to policy measure (5), are interventions affecting the credit standards applied by banks. *"Liquidity"* corresponds to policy measure (6) and covers policy actions affecting the liquidity position of banks as well as maturity and currency mismatches. *"Other"* comprises levies and taxes on financial institutions, limits to exposures and concentrations, and other measures. Finally, in the rows numbered (10), (11) and (12) we show the sum over all policy actions, capital-based actions and non-capital-based actions, respectively.

The majority of the interventions belong to the class of capital-based measures. As revealed by column (b1), in the core countries the share of these measures in all interventions amounts to 46.2%, while in the periphery countries the share is as high as 67.1%. The most frequently changed capital-based measures are adjustments of minimum capital requirements, followed by changes in risk weights and capital buffers (see rows (3), (4) and (1) in Table 1). In contrast, the shares of measures characterized as borrower-based, liquidity requirements, levies/taxes and limits to exposures are much smaller (see rows (5) to (8)). Irrespective of their type, the bulk of policy actions are tightenings; see columns (c.1) and (c.2).

Overall, Table 1 reveals the substantial diversity of the different types of macroprudential measures. Some of them operate on the asset side of financial institutions (e.g. "risk weights" or "limits on exposures and concentration") while others directly target the liability side (e.g. "capital buffers" and "minimum capital requirements"). The majority of borrower-based instruments affect banks' balance sheets only indirectly whereas most other measures exert a direct effect. Some measures operate on flows or transactions (e.g. many financial taxes) while others impose restrictions on stocks. Accordingly, the different types of macroprudential policy interventions might be transmitted very differently through the financial system and potentially have different consequences for banks' sovereign exposures. Ideally, one would thus assess the potential effects of each individual measure type, i.e. (1) to (9), separately. Unfortunately, this would render the econometric analysis infeasible as the number of policy actions within each measure type is very small. This could increase estimation uncertainty and potentially bias the results due to an insufficient variation in the macroprudential policy variables over time and across countries. In light of the heterogeneity of instruments and the aforementioned potential econometric problems, we decided to focus our subsequent analysis on the class of "capital-based" measures, which aggregates over instrument types (1) to (4). This appears warranted as these measure types, while not homogeneous, exhibit the similarity of directly affecting the regulatory capital requirement for banks. Consequently, our estimates presented below reflect the transmission of unsystematic shifts in (shocks to) the *average capital-based policy instrument* rather than in any of the individual instrument types (1) to (4). In contrast, the remaining non-capital-based macroprudential measures, i.e. (5) to (9), appear

too diverse to be meaningfully bundled.[15] Nevertheless, in Appendix C we present and briefly discuss the effects of shocks to the average *non-capital-based* policy measure.

Table 1: Macroprudential policy changes (1999-2018): Some descriptives

Type of policy change	Number of policy changes: countries core (a.1)	Number of policy changes: countries periphery (a.2)	Rel. frequency of each policy type: countries core (b.1)	Rel. frequency of each policy type: countries periphery (b.2)	Fraction of tightenings within each policy type: countries core (c.1)	Fraction of tightenings within each policy type: countries periphery (c.2)
Capital-based:						
(1) Capital buffers	17	10	12.9%	13.7%	100%	100%
(2) Loan-loss provisioning	2	5	1.5%	6.9%	50%	80%
(3) Min. cap. requirements	26	22	19.7%	30.1%	100%	100%
(4) Risk weights	16	12	12.1%	16.4%	56.3%	75%
Borrower-based:						
(5) Lending standards restrictions	19	1	14.4%	1.4%	94.7%	0%
Liquidity:						
(6) Liquidity requirements	16	8	12.1%	11.0%	100%	87.5%
Other:						
(7) Levy/Tax on financial institutions	15	2	11.4%	2.7%	73.3%	100%
(8) Limits on exposures	14	9	10.6%	12.3%	64.3%	77.8%
(9) Other measures	7	4	5.3%	5.5%	71.4%	100%
Sum:						
(10) All measures	132	73	100%	100%		
(11) Capital-based	61	49	46.2%	67.1%		
(12) Non-capital-based	71	24	53.8%	32.9%		

Notes: Only policy changes characterized as *(i) "legally binding"* and *(ii) either "tightenings" or "loosenings"*. Policy interventions with *"unspecified or ambiguous impact"* are excluded. The values in row (10) "all measures", in row (11) "capital-based" and in row (12) "non-capital-based" correspond to the column-by-column sum over policy changes (1) to (9), (1) to (4), and (5) to (9), respectively.

[15] Even within some of the categories (5) to (9), there might be important heterogeneity. Allen and Gale (2017) pointedly conclude their review of the literature on liquidity regulation as follows: *"With capital regulation there is a huge literature but little agreement on the optimal level of requirements. With liquidity regulation, we do not even know what to argue about."* (p. 155)

4.2 Construction of the capital-based macroprudential policy indicator

We follow the majority of existing studies and construct a discrete "dummy-type" macroprudential policy indicator (MPI) based on the *capital-based* policy changes.[16] In particular, the MPI comprises adjustments in the MaPPED categories *(i)* "capital buffers", *(ii)* "loan-loss provisioning", *(iii)* "minimum capital requirements" and *(iv)* "risk weights" (see Table 1).[17] We assign each individual policy change a value of +1 if it was a tightening, a value of -1 if it was a loosening and zero if the intervention is characterized as "unspecified or with ambiguous impact".[18] In case a country reports more than one policy change in a particular quarter, the associated discrete values are simply added up to arrive at the period-specific policy change indicator $PolChange_{i,t}$ for country i and period t.[19] In periods without capital-based macroprudential policy changes we have $PolChange_{i,t} = 0$. Next, given $PolChange_{i,t}$ we construct the MPI for country i as the cumulative sum over $PolChange_{i,t}$, i.e.:

$$MPI_{i,t} = MPI_{i,t-1} + PolChange_{i,t} = \sum_{j=0}^{j=t} PolChange_{i,j}.$$

The resulting country-specific cumulative $MPI_{i,t}$s are shown in Figure 1 alongside the number of tightenings and loosenings. The $MPI_{i,t}$ implies that each capital-based policy change has a potentially permanent effect on the indicator. Put differently, after a policy tightening, the MPI remains higher until the policy change is reversed or compensated for by a loosening of another capital-based instrument. Accordingly, the cumulative MPI is more suitable for reflecting the evolution of the overall tightness of capital-related macroprudential policy than the time series of period-by-period policy changes $PolChange_{i,t}$ (Akinci and Olmstead-Rumsey, 2018; Meuleman and Vander Vennet, 2020).

An important property of our MPI is that it implies a fully equivalent treatment of capital-based policy actions across types and magnitudes. We do not attempt to capture the (possibly time-varying) intensity of a measure or to weigh measures by the degree of their bindingness. Accordingly, the dummy-type MPI only reflects the *extensive margin* of capital-based interventions, i.e. their frequency and direction, but not their *intensive margin*. Ideally, one would like to measure the intensity of those policies. However, it is not straightforward to obtain a fully quantitative policy indicator due to the limited com-

[16] See Claessens et al. (2013), Cerutti et al. (2017a), Kuttner and Shim (2016), Bruno et al. (2017), Gambacorta and Pabon (2017), Boar et al. (2017), Altunbas et al. (2018), Akinci and Olmstead-Rumsey (2018) and Poghosyan (2020), among others.

[17] There is an additional category that might be considered here, "leverage-ratio restrictions". However, for the countries in our sample, MaPPED does not include changes in the regulation of banks' leverage ratio which are classified as either tightenings or loosenings in this category.

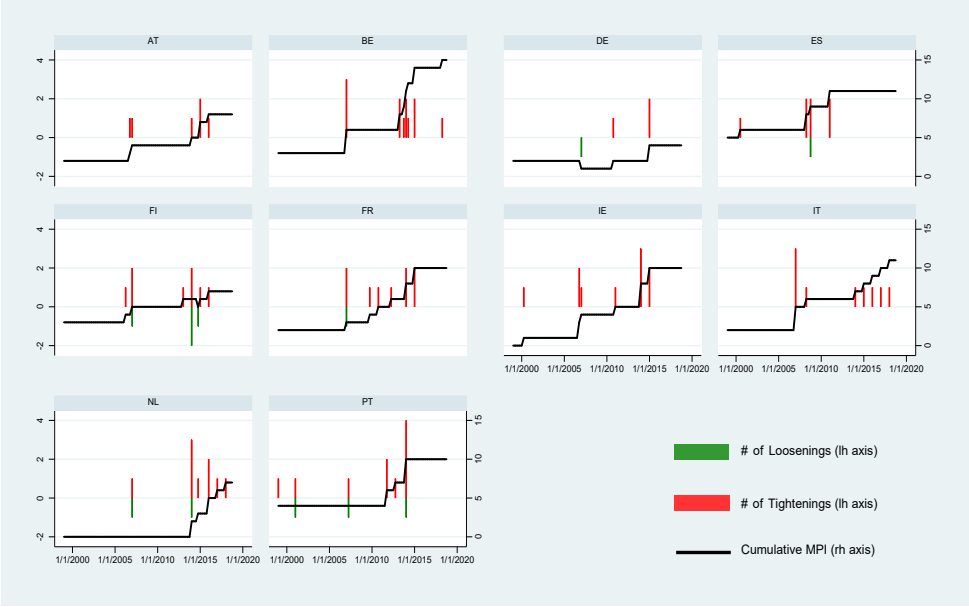
[18] Several interventions simultaneously contain a tightening and a loosening element, e.g. if the loan-to-value restriction is tightened for loans above a particular volume, but loosened for loans below that volume.

[19] For example, the Netherlands reports four tightenings and one loosening in 2014Q1. Thus, the policy change indicator for this period accordingly is $4 - 1 = 3$.

parability across countries and across measures (Kuttner and Shim, 2016; Cerutti et al., 2017b; Akinci and Olmstead-Rumsey, 2018; Alam et al., 2019).[20] In the face of this issue and given our objective of analyzing as broad a set of euro area countries and capital instruments as possible, we restrict our analysis to the dummy-type MPI which, notwithstanding 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.[21] 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.

Figure 1: Historical evolution of capital-based macroprudential policy



Notes: The bars show the number of tightenings and loosenings of capital-based instruments. The black line shows the evolution of the corresponding cumulative macroprudential policy indicator $MPI_{i,t}$.

5 Results

In the following, we present impulse responses across our country groups – the "core" countries of AT, BE, FI, FR, DE and NL, and the "periphery" economies of IT, ES, PT

[20] In particular, due to the 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, also within the same country, aggregation over intensities of policy changes is hindered by the mere heterogeneity across possible macroprudential measures.

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

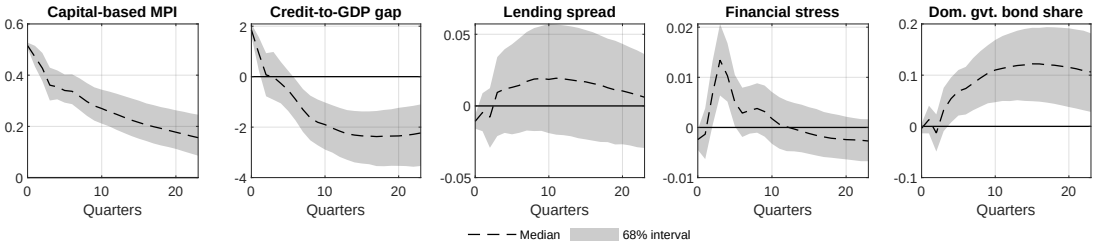
and IE – to shocks to the capital-based macroprudential indicator.[22]

5.1 Impulse responses to macroprudential policy shocks

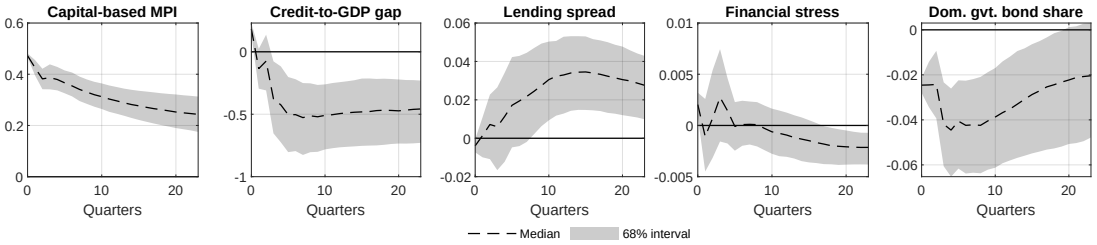
Figure 2 shows the responses of the model variables in the baseline model to a macroprudential policy shock - that is an unsystematic policy change - in the periphery (upper row) and core (bottom row) countries. The median impulse responses are depicted by the dashed lines. The shaded areas indicate the 68% credibility bound.

Figure 2: Response of baseline variables to a macroprudential policy shock

(a) Periphery countries



(b) Core countries



Notes: The median impulse responses are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. Responses of financial stress in percent; of Basel gap, domestic government bond share and lending spread in percentage points; of MPI dimensionless.

We see that in both country groups, the credit-to-GDP gap (Basel gap) displays a significant and persistent decline after a limited short-lived rise. Given that the Basel gap is widely viewed as an indicator of systemic financial vulnerability, our result suggests that tightenings of capital-based macroprudential policy might be effective in reducing excessive leverage in the non-financial private sector and thus systemic risk in the economy. The lending spread, i.e. the spread between the loan rate and the three-month EURIBOR rate, tends to increase after the macroprudential impulse, with the change being significant only in the core countries. The reactions of the Basel gap and the lending spread suggest the presence of adverse loan supply effects (see also Altavilla et al., 2019). Furthermore, the level of financial stress as proxied by the CLIFS tends to increase in the

[22] We abstain from presenting and discussing any results based on a fully pooled panel VAR covering all the ten countries. First, as explained in Section 3.1, there are structural reasons why one should expect the core economies to behave differently from their periphery counterparts. Second, as shown in Section 5, the reaction of banks' portfolios to unsystematic changes in macroprudential policy differs significantly between the two country groups. Accordingly, it is not surprising that in a fully pooled VAR, we obtain largely insignificant results – the latter being available upon request.

short run before falling to below average values after about four years. The short-run rise is significant only in the periphery economies, while the mid-term decrease turns out to be significant only in the core of the euro area.

Next, we turn to the main focus of our analysis - the reaction of the domestic government bond share on banks' balance sheets to unsystematic changes in capital-based macroprudential policy. In this regard, we observe a notable difference between the periphery and core economies of the euro area. In the periphery countries, there is a significant shift towards a higher exposure to domestic sovereign debt in banks' portfolios. This suggests that a tightening of capital-based measures induces a strengthening of the sovereign-bank nexus. By contrast, in the core economies of the euro area, the domestic government bond ratio on banks' balance sheets exhibits a significant drop after the macroprudential shock, which suggests a weakening of the sovereign-bank nexus.

Our results suggest that the effect on the domestic government bond share is not small from a quantitative point of view. An average tightening in the capital-based MPI reduces the credit-to-GDP gap in the periphery by more than two percentage points (pp) after three years. It also seems to increase lending spreads, but insignificantly so. The MPI tightening moreover increases financial stress in the short run (after around one year). Importantly, the MPI tightening also leads to an increase in the domestic government bond share starting after one year, with a persistent effect reaching a maximum of 0.12 pp after around three years. Similarly, for the core countries the credit-to-GDP gap falls by around 0.5 pp and the lending spread increases significantly by 3.5 basis points after 16 quarters. For core countries, there is also a significant decrease in financial stress which sets in after about four years. In contrast to the periphery, in the core the domestic government bond share reaches a trough of 4.2 basis points below its initial value after four quarters. However, given that our MPI indicator amalgamates capital-based regulatory changes of different varieties and across different countries, it is hard to interpret its quantity. Therefore, while noting that quantitative effects appear economically significant, in what follows, we focus on the qualitative effects of capital-based macroprudential regulation.

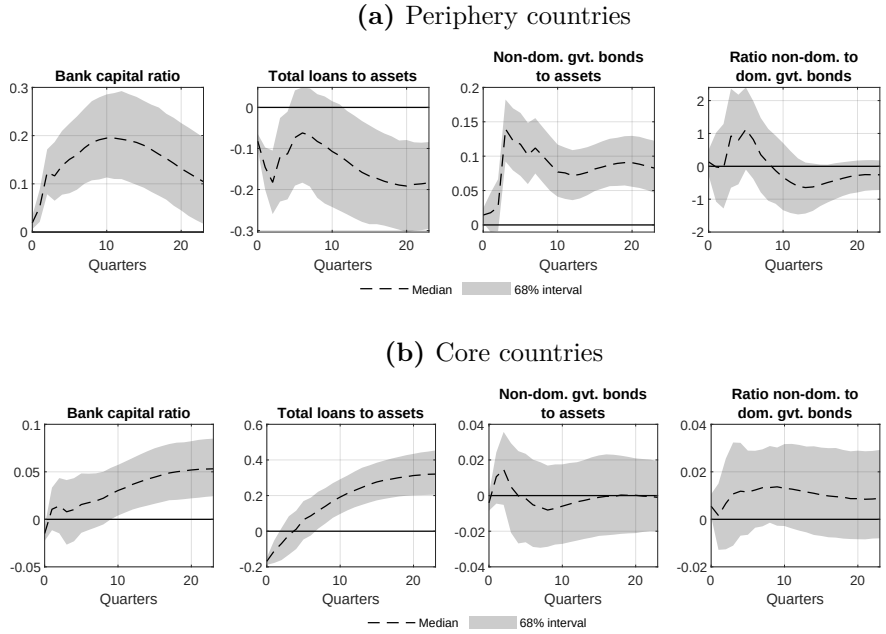
Adjustments in the capital ratio and the portfolios of banks. Now, we take a closer look at the changes in banks' capital ratio (inverse of the leverage ratio) and the adjustments in banks' portfolios in the face of shocks to capital-based macroprudential policy. In particular, we run adjusted versions of our panel VAR model, each time replacing the banks' domestic sovereign bond holdings ratio by either the capital ratio, or the ratio of loans to total assets, or the ratio of non-domestic government bonds.

As revealed by the first two plots for each country group in Figure 3, an unsystematic tightening of capital-based macroprudential policy leads to a persistent increase in banks' capital ratio. This indicates that such policy interventions tend to be effective not only in reducing systemic financial vulnerability as proxied by the Basel gap (see Figure 2) but are also effective in increasing the loss-absorption capacity (resilience) of the banking sector.

Regarding the bank portfolio adjustments, we observe a marked heterogeneity between

the two country groups. As shown in the second column of Figure 3, in the periphery economies banks' loan volume declines relative to total assets after a shock to capital-based macroprudential policy. By contrast, in the core countries the corresponding ratio increases, albeit after a short-lived initial decline. The response of the non-domestic sovereign bond holdings ratio also differs across the two country groups. In the periphery countries, it increases significantly but shows barely any reaction in the core economies. Hence, our findings suggest that periphery banks adjust their portfolios broadly towards a higher holding of government bonds, i.e. domestic sovereign bonds as well as foreign sovereign bonds.

Figure 3: Response of other banks' balance sheet items to a macroprudential policy shock



Notes: The median impulse responses are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. All responses in percentage points.

However, the last column in Figure 3 also shows that the periphery-banks' adjustment of government bond holdings seems to be in favour of domestically issued bonds. The ratio of foreign government bond holdings to domestic government bond holdings declines after a temporary rise in response to a capital-based macroprudential policy shock. In contrast, there are no such tendencies towards a stronger home-bias within banks' sovereign debt portfolios in the core economies.

5.2 Some explanations from the theoretical literature

What might explain the different reactions across the country groups to unsystematic changes in macroprudential policy? At first glance, the adjustments taking place in the periphery countries seem unsurprising, i.e. if the ability of banks to improve their regulatory capital position by issuing equity or via retained earnings is limited, a tightening

of capital-based regulatory instruments might force them to shift their portfolios towards assets with lower risk weights, like sovereign bonds. As noted in the Introduction, this is the concern raised by many observers regarding the possible unintended effects of macroprudential regulation on the sovereign-bank nexus. However, this is only one possible explanation, as the existing theoretical and empirical literature on the risk-shifting effects of capital regulation draws a much more nuanced picture (VanHoose, 2007; Galati and Moessner, 2018). In the following, we discuss some existing theories which might contribute to explaining our findings.[23]

Several studies based on portfolio selection models in the tradition of the *moral hazard* theory show that if utility-maximizing banks are sufficiently risk-neutral, an increase in capital requirements will incentivize them to choose a riskier asset mix (Kahane, 1977; Koehn and Santomero, 1980; Kim and Santomero, 1988; Jeitschko and Jeung, 2005). In fact, such banks increase business risk to offset the impact of forced lower leverage and thus, a lower return on equity. Under *full liability* such unintended behavior might be reduced or even eliminated by appropriate, i.e. auxiliary fair, risk weights. However, Rochet (1992) demonstrates that under the more realistic assumption of *limited liability* even appropriate risk weights are not sufficient to force banks with low risk aversion to reshuffle their portfolios towards less risky assets.[24] In contrast, banks exhibit the opposite investment behavior if they are relatively more risk-averse. Overall, this strand of literature indicates that banks' risk aversion is a crucial parameter governing the portfolio adjustments in response to tightenings of capital regulation. These theories would be aligned with our results if banks in core countries were more risk-neutral than those in the periphery during our sample. Given the economic and financial turmoil in the periphery countries during much of this period, this might be a reasonable assumption. However, a statement on the degree of risk aversion across euro area countries is beyond the scope of our analysis.

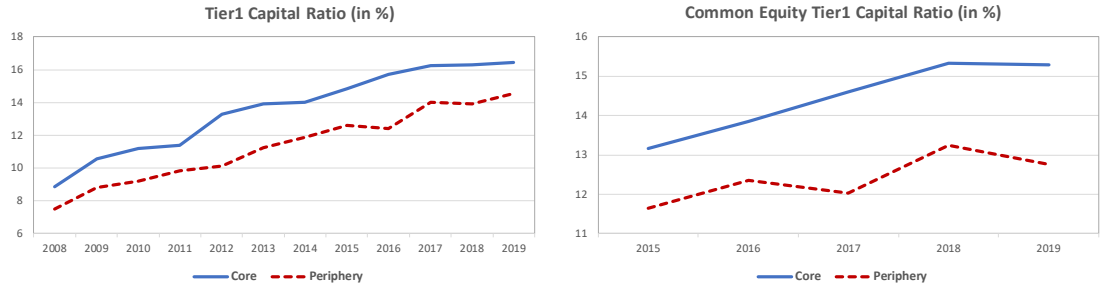
Most of the papers in the *moral hazard* theory assume either that bank capital is

[23]There are several reasons why these theoretical explanations should be viewed as purely suggestive. First, none of the models considered exactly matches our research question and analysis. Second, the theories are based on various, sometimes very distinct assumptions. While we believe those assumptions to be largely plausible for the ten euro area countries in our sample, we are not able to test them within our framework. Third, a large part of the theoretical results is based on partial-equilibrium models. As acknowledged in the corresponding papers, these results only provide rough tendencies about what might be observed at the macroeconomic level, i.e. for the banking sector as a whole. Similar qualifications are warranted regarding the related empirical evidence we discuss below, since the existing studies do not cover the same set of countries and resort to microeconometric data and techniques.

[24]In a framework also accounting for deposit insurance, Gennotte and Pyle (1991) find that increased stringency in capital standards may induce banks to incur greater portfolio risk as long as the bank is not restricted to zero net present value investments. Hellmann et al. (2000) demonstrate in a dynamic model of moral hazard that the higher is the degree of competition in the banking sector, the more likely it is that tightenings of capital regulation will be associated with adverse effects on banks' risk taking. In a general-equilibrium set-up, Frazzini and Pedersen (2014) also show that leverage-constrained investors (not necessarily banks) react to a tightening of the constraint by increasing investments in more risky (high beta) assets. Kashyap et al. (2014) show in an extended Diamond-Dybvig-type model how a more stringent capital requirements, while reducing the probability of a bank run, forces banks to reshuffle their portfolios towards riskier assets.

exogenous, solely driven by regulation, or that, due to the absence of adjustment costs, the actual capital ratio is always equal to the regulatory one. In contrast, the *capital buffer theory*, as it is known, endogenizes banks' optimal choice of capital ratio. The buffer corresponds to the capital held in excess of the regulatory requirement (Burser et al., 1981; Marcus, 1984; Calomiris and Kahn, 1991; Calem and Rob, 1999). In that theory, banks face the trade-off between holding a higher capital buffer in order 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 a tightening of capital requirements, banks with *high* capital buffers aim at maintaining their capital buffers by increasing both their capital and the riskiness of their portfolio. In contrast, banks with *low* buffers tend to rebuild their buffer by reducing the riskiness of their asset portfolio while simultaneously making attempts to raise capital by issuing equity or via retained earnings. Several studies provide empirical evidence in support for such behavioral patterns, for example 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[25] According to the capital buffer theory, our empirical results presented in Figures 2 and 3 would be observed if banks' excess buffers tended to be elevated in core countries and relatively smaller in periphery countries. In that case, core countries' banks would respond to a tightening of capital-based macroprudential policy by also increasing the riskiness of their portfolios, i.e. by investing more in risky loans while reducing exposures to the safer sovereign bonds. Banks in the periphery countries would undergo the opposite portfolio adjustment. Support for such an interpretation is provided in Figure 4, which shows the average regulatory capital ratios (Tier 1 and Common Equity Tier 1) for the two country groups. In the core countries, the two ratios are strictly higher over the period for which the data is available.

Figure 4: Regulatory capital ratios, averages for each country group



Notes: Regulatory capital ratios (in percent of risk-weighted assets). Weighted averages across the 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 total assets of country i's banks and $\sum_{i=1}^{N} TA_{i,t}$ are banks' total assets for the corresponding country group. Length of time series is restricted by data availability. Source: European Central Bank, Statistical Data Warehouse (SDW).

Several recent papers provide additional rationales – albeit only indirect ones – for why

[25]Furthermore, based on data covering 251 banks in 36 countries, Gonzalez (2005) finds evidence indicating that tightenings in capital-related regulation increase banks' risk-taking incentives by reducing their charter value. Moreover, this effect is significantly stronger in countries with on average stricter regulation since the latter tends to reduce banks' charter value.

poorly capitalized banks, when put under pressure by capital regulation, could increase their holdings of domestic sovereign bonds. Crosignani (2021) builds a theoretical model that shows how the creditworthiness of a sovereign can affect the bank-sovereign nexus. The model is explicitly geared towards explaining dynamics of the euro area periphery during the European sovereign debt crisis. In particular, the author shows that in an equilibrium with low capital requirements, banks will have incentives to tie their fate to that of the sovereign and to increase holdings of domestic sovereign debt. Given that weak bank capitalization was much more common in the periphery than the core countries (see Figure 4), this helps to explain why banks would react to pressure (here from the macroprudential side) by increasing their exposure to sovereign debt.[26] On the contrary, better capitalised financial sectors in the core would rather choose to lend to productive sectors than to invest in sovereign debt. Furthermore, Farhi and Tirole (2018) identify a channel which makes banks focus on domestic sovereign debt in a situation of either weak bank balance sheets or public finances. In such a case, the return on sovereign debt increases for the no-bailout case, but is unchanged in the case of a bailout (all relative to safe foreign sovereign debt). Hence, due to this asymmetry of returns banks will invest more in domestic sovereign debt even if it comes with a higher risk.

6 Robustness

We assess the robustness of our results by considering several alternative model specifications. First, we discuss the importance of and potential biases through policy announcements. Second, we extend our baseline model by an additional variable like real estate prices, government bond yields, stock market indices and others, which are potentially important for macroprudential policy decision making and/or for properly accounting for policy announcements and news. Third, we perturb our baseline specification by considering different identification schemes for the unsystematic part of macroprudential policy, different lag orders, alternative sample periods and the exclusion of Ireland as a potential outlier. Finally, we use the IMF's iMaPP database for the construction of the macroprudential policy indicator, as well as adjusted versions of the MPI based on MaPPED. Our main results are qualitatively robust to all these checks, and quite similar quantitatively as well. In the following, we focus on impulse responses to the domestic government bond share for brevity. The responses to other variables are also largely robust, however.[27]

[26] In fact, our capital-based MPI shock of course affects capitalization and thus the possibility that a bank or "financial sector" will be undercapitalized in Crosignani's model. So the sovereign-bank nexus should in fact only increase after a regulatory capital tightening if the (temporary) contractionary effect on firms outweighs the stabilising effect of more capital in the medium run.

[27] Results are available upon request.

6.1 Policy announcements

In our baseline analysis, we construct the MPI based on actual implementation dates as recorded in MaPPED. However, many macroprudential interventions - even if unexpected - are announced several quarters in advance. Banks as well as the economy as a whole might thus react to such announcements by starting to adjust their liability structure, asset portfolios and general behavior well in advance of the actual policy implementation. The presence of such announcements effects - if not properly accounted for - might bias our results by leading to a non-invertible VAR representation (Leeper et al., 2013). In particular, the VAR based on a set of observable state variables might not be sufficient (spanning problem) to uncover the underlying structural shocks. In our case, this problem is most likely to be less of an issue for two reasons. First, the variables and the number of lags in our VAR are selected such that the *systematic* reactions to current and future macroprudential policy are captured. Since the resulting Choleski shocks in the equation of the macroprudential policy indicator $MPI_{i,t}$ are White Noise, we interpret them as reflecting the unsystematic policy component. Second, Sims (2012) shows that the potential non-invertibility problem is strongly mitigated if forward-looking variables are included in the model. Our baseline VAR is consistent with this requirement as it includes two such variables. In particular, the CLIFS condenses the information from various fast-moving financial market variables like equity returns, bond yields and spreads and stock market volatility. The lending spread also reflects expectations about future developments.[28] We also run robustness checks in which, each time, the VAR is extended by one of the following strongly forward-looking variables: the CDS spread, the yield on 10-year sovereign bonds, the stock market sub-index covering the stocks of banks. The corresponding results are discussed in Section 6.2 and reveal qualitatively and quantitatively the same picture as our baseline analysis.

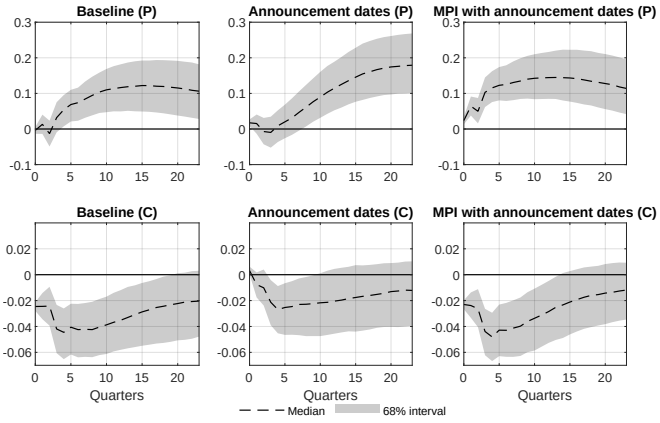
To provide additional evidence addressing the importance and potential biases associated with announcement effects, we construct a capital-based MPI based on announcement rather than implementation dates, i.e. $MPI^{ann}_{i,t}$. MaPPED contains the corresponding information for around 70% of the capital-based policy actions. Given this announcement-based MPI, we perform two robustness checks. First, we estimate the VAR by replacing the baseline implementation-date-based MPI by its announcement-based counterpart $MPI^{ann}_{i,t}$. In this case, we start our sample in 2004Q1 instead of 2005Q1 to keep the events roughly the same. Apart from these two changes, the model and the identification scheme remain identical. The Choleski shock to $MPI^{ann}_{i,t}$ is interpreted as the proxy for the unsystematic policy component. Second, we extend the VAR by including the $MPI^{ann}_{i,t}$ as an additional variable ordered second, just after the implementation-date-based MPI. The latter's Choleski shock is viewed as capturing the unsystematic part of macroprudential policy. In this case the systematic component of macroprudential policy explicitly controls for announcements.

The impulse responses of banks' balance sheet share of domestic government bonds

[28] The lending spread is based on the loan rate charged on *new* loans *("New Business")* only.

under the two specifications including the announcement-based policy indicator $MPI_{i,t}^{ann}$ are shown in Figure 5 (middle and rightmost column). As can be seen, the results are very similar to those obtained with our baseline VAR (leftmost column). This indicates, that each of these three specifications identifies roughly the same shock as a proxy of the unsystematic component of capital-based macroprudential policy.

Figure 5: Robustness: Policy announcements (shown: domestic gov. bond share)



Notes: The median impulse responses of the variable domestic government bond share for the respective models are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. (P) and (C) indicate impulse responses for "periphery" and "core" countries. "MPI and announcement dates" uses the announcement dates of macroprudential policy changes where available as a sixth variable in the VAR. Sample from 2004Q1 to 2018Q4. Responses in percentage points.

6.2 Extended panel VAR models

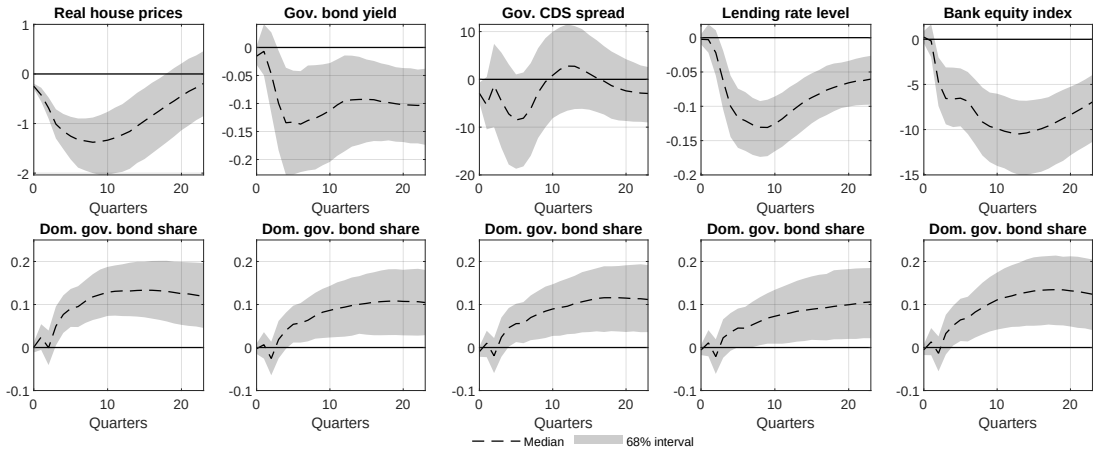
Next, we estimate extended versions of our panel VAR model, each including one of the following additional variables: real estate prices, i.e. nominal house prices deflated by the GDP deflator, the 10-year government bond yield, CDS spreads for sovereign debt, the level of lending rates, and the stock market price index for banks. These variables are potentially relevant for macroprudential policy as they might signal the build-up of vulnerabilities in the real estate sector or imminent tensions in capital or credit markets.

Figures 6 and 7 show the responses of each of these additional variables (top row) alongside the corresponding reaction of banks' domestic government bond share (bottom row) to unsystematic changes in macroprudential policy for the periphery and core countries, respectively. House prices increase in the core, but fall in the periphery. The 10-year government bond yield, lending rates, and the CDS spread decline significantly for both core and periphery after the macroprudential tightening. This could be due to some signalling effect of more stable financial markets provided by the macroprudential intervention, or is likely the effect of some comovement of monetary policy as the credit-to-GDP gap falls.[29] Finally, the decline in the stock market price index for banks might

[29]It should be noted that the decrease in government bond yields almost vanishes in the medium term for the periphery, just when the effect on the nexus – as indicated by the domestic government bond share – peaks.

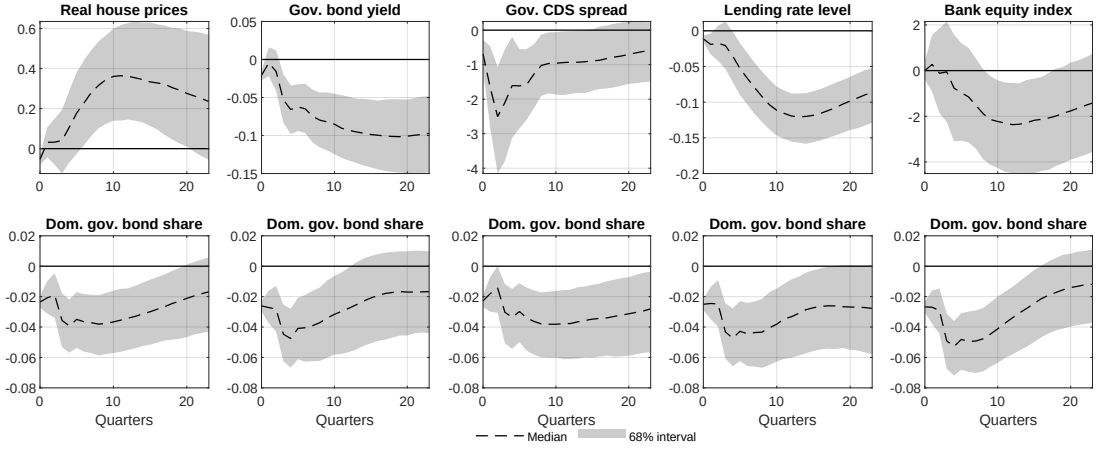
be the reflection of a lower expected return on equity due to the potential leverage decline induced by the regulatory tightening. The responses of the domestic government bond share in all these specifications are very similar to the baseline in terms of both, dynamics and magnitude.

Figure 6: Extension: Panel VAR with additional sixth variables (Periphery)



Notes: Impulse responses to a shock to capital-based macroprudential policy in a VAR with six variables. The figure shows the responses of the different series that are added as a sixth variable to the baseline, as well as the associated reaction of the domestic government bond share (always below the respective sixth variable). The median impulse responses are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. Response of real house prices, all others in percentage points.

Figure 7: Extension: Panel VAR with additional sixth variables (Core)



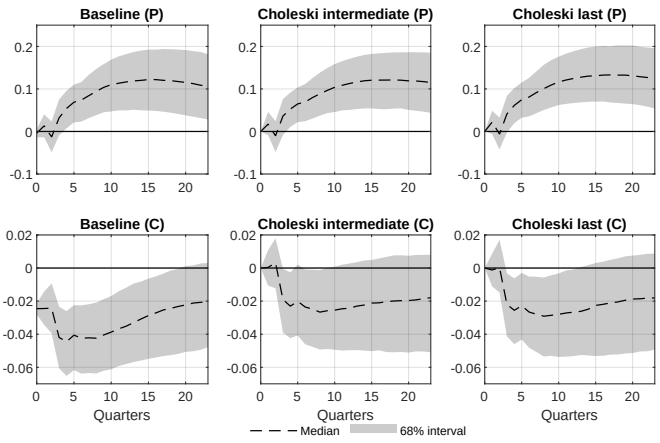
Notes: Impulse responses to a shock to capital-based macroprudential policy in a VAR with six variables. The figure shows the responses of the different series that are added as a sixth variable to the baseline, as well as the associated reaction of the domestic government bond share (always below the respective sixth variable). The median impulse responses are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. Response of real house prices in percent, all others in percentage points.

6.3 Identification, lag structure, sub-samples and detrending

Identification. We replace the baseline structural shock identification scheme described in Section 3.3 with two alternative recursive orderings. The first assumes that the MPI is ordered after the credit-to-GDP gap and banks' domestic sovereign bond share but before the CLIFS and the interest spread. Thus, the latter two variables are allowed to respond immediately to a macroprudential policy shock while the former two variables respond with a delay. Hence, the MPI is no longer the slowest-moving variable in the model as it can react immediately to innovations in the equations for the credit-to-GDP gap and the domestic government bond holdings share. The second alternative ordering assumes that the MPI is ordered last. Accordingly, on impact, the macroprudential policy shock affects only the MPI itself while the remaining variables start to react in the following quarter. The two alternative orderings assume a high degree of short-run flexibility to macroprudential policy as it can react to some or all exogenous shocks within a quarter. However, as discussed in Section 3.3, the empirical evidence and the historical experience are much more in favour of our baseline Choleski ordering.

Figure 8 shows the reaction of banks' share of domestic government bonds under the baseline alongside the two alternative Choleski orderings. As can be seen, variations in the recursive identification scheme leave our main result qualitatively unchanged. In particular, the increase in banks' holdings of domestic government debt in the periphery remains highly significant and essentially unaffected in its magnitude.

Figure 8: Robustness: Choleski ordering (shown: domestic gov. bond share)



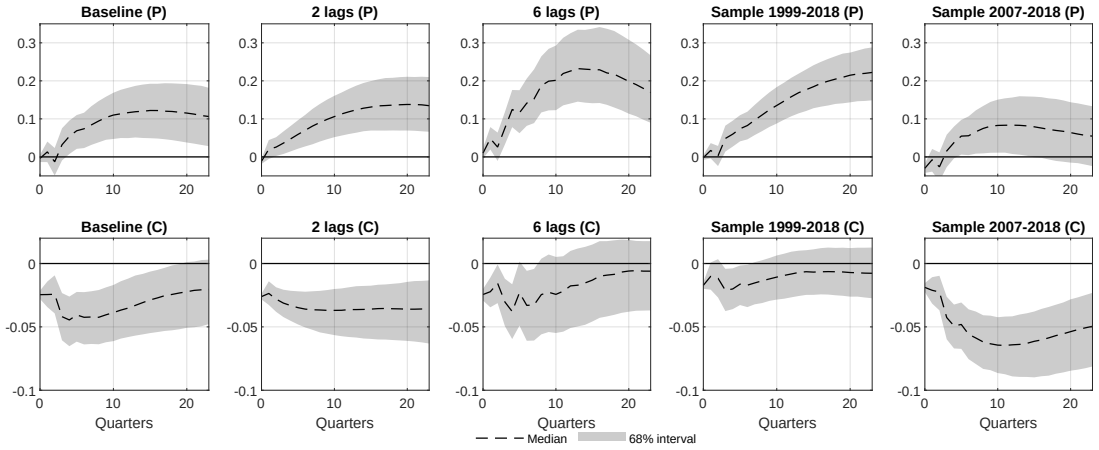
Notes: The median impulse responses of the domestic government bond share for the respective models are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. (P) and (C) indicate impulse responses for "periphery" and "core" countries. Responses in percentage points.

Lag structure, sample period and detrending. Our results are also qualitatively unchanged if the panel VAR model is estimated with between two and six lags instead of four (see Figure 9).[30] The same holds with respect to two alternative sample periods. In

[30]Results for three and five are very similar to the ones shown.

particular, while our baseline analysis focuses on the period 2005 to 2018, in the robustness experiments we also consider the years since the adoption of the euro (1999 to 2018) and the period since the outbreak of the global financial crisis (2007 to 2018).

Figure 9: Robustness: Lag structure and sample period (shown: domestic gov. bond share)



Notes: The median impulse responses of the variable domestic government bond share for the respective models are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. (P) and (C) indicate impulse responses for "periphery" and "core" countries. Responses in percentage points.

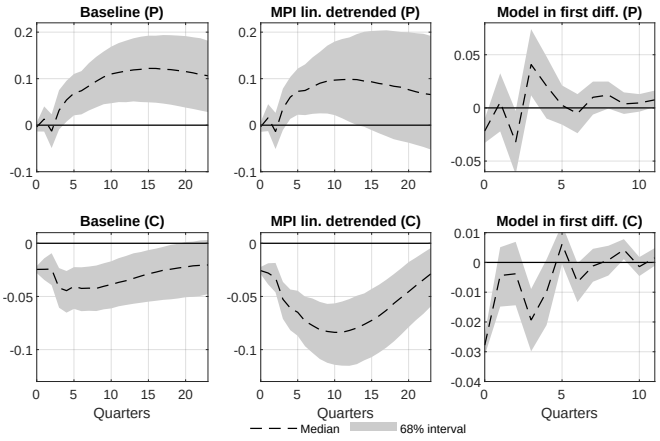
Finally, we explore the robustness of our results to different detrending assumptions. In particular, we conduct two exercises. First, a country-specific linear trend is removed from the cumulative macroprudential policy indicator $MPI_{i,t}$ and the resulting deviation-from-trend enters the VAR instead of the cumulative $MPI_{i,t}$. Second, we estimate a version of the VAR in which each variable except the lending spread enters as a first difference relative to the previous quarter. The corresponding responses of the share of domestic government bonds on banks' balance sheets are given in Figure 10. Our baseline results are again confirmed. Note that as expected, when the model variables are in first differences, the impulse responses are much less persistent, being insignificant at horizons larger than 10 quarters.

6.4 Alternative macroprudential policy indicators

Next, we assess the robustness of our findings with regard to the MPI. First, we construct two alternative policy indicators based on MaPPED in which, however, we adjust for cross-country inconsistencies regarding the reporting of measures related to Basel III. Second, we construct an analogous capital-based indicator based on the Integrated Macroprudential Policy (iMaPP) collected by Alam et al. (2019) and provided by the IMF.

MPIs adjusted for Basel III measures. The third installment of the Basel Accords, better known as Basel III, was agreed upon by the members of the Basel Committee on Banking Supervision in November 2010. The accord was developed in response to the

Figure 10: Robustness: Detrending the MPI (shown: domestic gov. bond share)



Notes: The median impulse responses of the variable domestic government bond share for the respective models are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. (P) and (C) indicate impulse responses for "periphery" and "core" countries. Responses in percentage points.

regulatory deficiencies revealed by the global financial crisis of 2007-2008 and aimed at strengthening the resilience of the banking system by tightening capital requirements and increasing bank liquidity. Countries that committed to adopting Basel III were expected to translate the accord into national law within a certain period of time.[31] In the EU, countries had to impose the new regulatory requirements by gradually tightening them during a pre-specified phase-in period until a final level is reached. Countries are each allowed to shorten the phase-in period or to impose a more stringent final regulation but not do the opposite.

However, although the Basel III regulations apply equally to all EU member states, their appearance in MaPPED is rather heterogeneous and inconsistent across countries. In particular, there is considerable variation in the way national authorities have reported the activation and subsequent adjustments of the *(i) Minimum Common Equity Tier 1 Capital Ratio (CET1)*, the *(ii) Minimum Tier 1 Capital Ratio*, the *(iii) Capital Conservation Buffer (CCoB)*, and the additional capital requirements for *(iv) Global Systemically Important Institutions (G-SIIs)* as well as for *(v) Other Systemically Important Institutions (O-SIIs)*.[32] For example, several national authorities do not report anything regarding some of these measures, while others only report a single macroprudential tightening on the date when the corresponding measure reached its final level and was thus fully phased in. Lastly, a set of countries explicitly reports each of the stepwise tightenings along the phase-in path for some of the aforementioned Basel III measures.

To cope with this heterogeneity, we construct two adjusted macroprudential policy

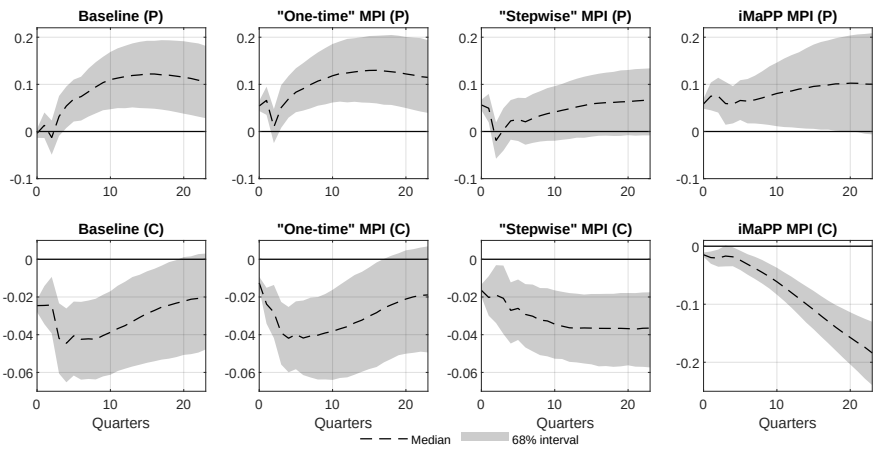
[31] See BCBS (2011, 2012) and `https://www.bis.org/bcbs/basel3/b3_trans_arr_1728.pdf`.

[32] The Basel III Accord prescribes the following regulatory adjustments: the *Minimum Common Equity Tier 1 Capital Ratio (CET1)* to be set to 3.5% in 2013Q2 and raised to 4.5% in 2015Q1, the *Minimum Tier 1 Capital Ratio* to be set to 4.5% in 2013Q2 and raised to 6.0% in 2015Q1, the *Capital Conservation Buffer (CCoB)* to be set at 0.625% in 2016Q1 and raised to 2.5% in 2019Q1, the G-SII and O-SII buffers to be activated in 2016Q1 and increased until 2019Q1 by a constant bucket-specific increment each year.

indicators based on MaPPED. In the first, termed "MPI$^{\text{stepwise}}$", we assume that each tightening step along the envisaged phase-in of the corresponding measure should be reflected by an entry of +1 in the discretely coded indicator. National MPIs are adjusted accordingly in the case that a country reported the particular Basel III measure differently, i.e. did not report it at all or reported it only as a single tightening. The cases in which a country officially announced and implemented a faster phase-in for a particular measure are accounted for. The changes were verified based on macroprudential notifications collected and published by the ESRB.[33] In the second adjusted MPI, termed "MPI$^{\text{one-time}}$", we replace each of the aforementioned phased-in measures with a single tightening in the quarter in which the first step of the corresponding measure was activated. Appendix B describes the precise adjustments performed to arrive at MPI$^{\text{stepwise}}$ and MPI$^{\text{one-time}}$.

Figure 11 summarizes the impulse responses of banks' domestic government bond holdings ratio to an innovation in each of the two alternative indicators. Overall, the reaction to both alternative shocks is quite similar to our baseline. However, regarding the timing of the response of the government bond holdings ratio to the alternative shocks, it appears that the increase in the ratio occurs more swiftly, i.e. the ratio begins to rise on impact of both shocks. The quantitative effects on periphery countries' sovereign exposures are also larger for the one-time indicator, i.e. we observe a maximum increase of 14% instead of 11% of the share.

Figure 11: Robustness: Other macroprudential indicators (shown: domestic gov. bond share)



Notes: The median impulse responses of the variable domestic government bond share for the respective models are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. (P) and (C) indicate impulse responses for "periphery" and "core" countries. "One-time MPI" and "Stepwise MPI" uses our capital-based baseline MPI with adjustments for the phase-in of Basel III measures (see text). "iMaPP" uses an indicator based on the "Integrated Macroprudential Policy" database collected by Alam et al. (2019). Responses in percentage points. Note that the y-axis for "iMaPP" differs in scaling from the other y-axes in the bottom row.

[33] See `https://www.esrb.europa.eu/national_policy/shared/pdf/esrb.measures_overview_macroprudential_measures.xlsx?b4d0d267f4fe73eaeca1caa84e946109`.

MPI based on iMaPP. Finally, we construct a dummy-type capital-based MPI based on iMaPP covering the categories *Countercyclical Buffers (C1.CCB)*, *Conservation Buffers (C2.Conservation)*, *Minimum requirements and risk weights (C3.Capital)*, *Leverage requirements (C4.LVR)* and *Loan-loss provisioning (C5.LLP)*. In contrast to MaPPED, iMaPP has a more limited coverage of capital-based measures in the EMU for the period before 2011. In addition, in some cases there are differences in how the two databases characterize measures. For example, sometimes a policy action is described as "with ambiguous impact" in one database while being characterized as a "tightening" in the other. Since a harmonization of iMaPP and MaPPED is beyond the scope of our analysis, we take such differences as given. Figure 11 summarizes the reaction of the variables to a shock to the capital-based iMaPP indicator. The impulse responses deliver a qualitatively similar pattern as reported before.[34] While for core countries the response of the domestic government bond share is slower but more persistent, it is both qualitatively and quantitatively very similar for the periphery. Therefore, our findings do not seem to be driven by the choice of macroprudential database.

7 Conclusion

Euro area countries put substantial effort into refining their regulatory framework in the aftermath of the global financial crisis. The objective was to strengthen banks' resilience by imposing regulatory reforms. However, concerns have been raised that capital-based macroprudential instruments, i.e. those related to bank capital regulation, might foster the unintended side effect of intensifying the sovereign-bank nexus, thus potentially undermining financial stability.

Using panel VAR models, we investigate how euro area banks' incentives to increase their exposure to domestic sovereign debt is affected by unsystematic changes in (shocks to) capital-based macroprudential policy measures. We refer to the Macroprudential Policy Evaluation Database (MaPPED) to construct a macroprudential policy indicator. Our findings suggest that periphery countries' banks increase their government bond holdings relative to total assets in response to an unsystematic macroprudential policy tightening. The adjustment of the government bond portfolio is characterized by a home bias, i.e. the holdings of domestic government bonds increase relative to foreign government bonds. Thus, stricter capital-based macroprudential policy measures seem to contribute to strengthening the sovereign-bank nexus. On the contrary, core countries' banks extend the loan volume relative to total assets rather than expanding their government bond holdings. Our results are robust to various alternative model specifications. They hold for different shock identification schemes, different lag orders, different periods under consideration as well as different macroprudential policy indicators derived on the basis of alternative calculation methods or alternative databases.

[34]Note that in a series of additional exercises, we found that our results also hold when estimating the VAR with the iMaPP-based MPI over the periods 1999 to 2018 and 2007 to 2018. The results are not reported here, but are available upon request.

We believe that capital-based macroprudential policy is a successful instrument for increasing the loss-absorption capacity and resilience of banks. However, our findings suggest that this type of policy should take into account the potential unintended consequence of a growing sovereign-bank nexus in countries with poorly capitalized banks. This concern is particularly pressing given the current strong increase in public debt levels on the back of the COVID-19 pandemic. An increase of macroprudential buffer requirements – many of which have been lowered across much of the euro area upon the onset of the pandemic – should take into account its potential effect on the sovereign-bank nexus documented in this paper.

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A Data

The macroeconomic data are taken from the ECB's Statistical Data Warehouse (SDW) covering the period 1999Q1-2018Q4.

- MFI loan volume
- Nominal GDP
- Lending rates
- Financial stress indicator, monthly frequency,
  `CLIFS.M.**._Z.4F.EC.CLIFS_CI.IDX`
  Converted to quarterly averages by using the monthly values.
- MFIs' holdings of domestic government bonds, outstanding amount (stock) in millions of euro, monthly frequency,
  `BSI.M.**.N.A.A30.A.1.U6.2100.EUR.E`
  Converted to quarterly end-of-period values based on the monthly observations.
- MFIs' holdings of government bonds issued by other EMU countries, outstanding amount (stock) in millions of euro, monthly frequency,
  `BSI.M.**.N.A.A30.A.1.U5.2100.EUR.E`
  Converted to quarterly end-of-period values based on the monthly observations.
- MFIs' holdings of government bonds issued by countries outside the EMU, outstanding amount (stock) in millions of euro, quarterly frequency,
  `BSI.Q.**.N.A.A30.A.1.U4.2100.Z01.E`
- Total assets of a country's MFIs, outstanding amount (stock) in millions of euro, monthly frequency,
  `BSI.M.**.N.A.T00.A.1.Z5.0000.Z01.E`
  Converted to quarterly end-of-period values based on the monthly observations.

The set of countries comprises: Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Ireland (IE), Italy (IT), the Netherlands (NL) and Portugal (PT). The country acronyms are to be inserted in the series' codes to replace the placeholder **. The macroprudential indicators are derived from the Macroprudential Policy Evaluation Database.

B Alternative macroprudential policy indicators

We construct the two alternative manually adjusted macroprudential policy indices based on MaPPED as follows:

- $\text{MPI}^{\text{stepwise}}$:
  - Minimum Common Equity Tier 1 Capital Ratio (CET1): insert a tightening in 2013Q2 for AT, DE, ES, FI, FR, IE, IT, NL, PT; insert a tightening in 2014Q1 for AT, DE, ES, PT.[35]
  - Minimum Tier 1 Capital Ratio: insert a tightening in 2013Q2 for AT, DE, ES, FI, FR, IE, IT, NL, PT; insert a tightening in 2014Q1 for AT, DE, ES.[36]
  - Capital Conservation Buffer (CCoB): insert tightenings in 2016Q1, 2017Q1, 2018Q1 and 2019Q1 for AT, BE, DE, FR, ES, IE, NL, PT.[37]
  - G-SII Buffer: insert tightenings in 2016Q1, 2017Q1, 2018Q1, 2019Q1 for AT, BE, DE, FI, FR, ES, IE and NL.
  - O-SII Buffer: insert tightenings in 2016Q1, 2017Q1, 2018Q1, 2019Q1 for AT, BE, DE, FR, ES, IE, IT, PT; insert tightenings in 2017Q1, 2018Q1, 2019Q1 for FI.
- $\text{MPI}^{\text{one-time}}$:
  - Minimum Common Equity Tier 1 Capital Ratio (CET1): remove tightening in 2015Q1 for AT, BE, DE, ES, FR, IE; remove tightening in 2014Q1 for BE, FR, IE; insert tightening in 2013Q2 for AT, DE, ES, FR, IE.
  - Minimum Tier 1 Capital Ratio: remove tightening in 2015Q1 for AT, BE, DE, ES, FR, IE; remove tightening in 2014Q1 for BE; insert tightening in 2013Q2 for AT, DE, ES.
  - Capital Conservation Buffer (CCoB): insert a tightening in 2016Q1 for AT, BE, DE, ES, FR, IE, NL, PT.
  - G-SII Buffer: remove tightenings in 2017Q1, 2018Q1 and 2019Q1 fot IT; insert a tightening in 2016Q1 for AT, BE, DE, FI, FR, ES and NL.
  - O-SII Buffer: FI is left unchanged; remove tightenings in 2017Q1, 2018Q1, 2019Q1 for NL; insert a tightening in 2016Q1 for AT, BE, DE, FR, ES, IE, IT, PT.

[35] In FI, IT and NL the CET1 was phased in at a faster pace and was fully implemented in 2014Q1.

[36] In FI, IT, NL and PT the Minimum Tier 1 Capital Ratio was phased in at a faster pace and was fully implemented in 2014Q1.

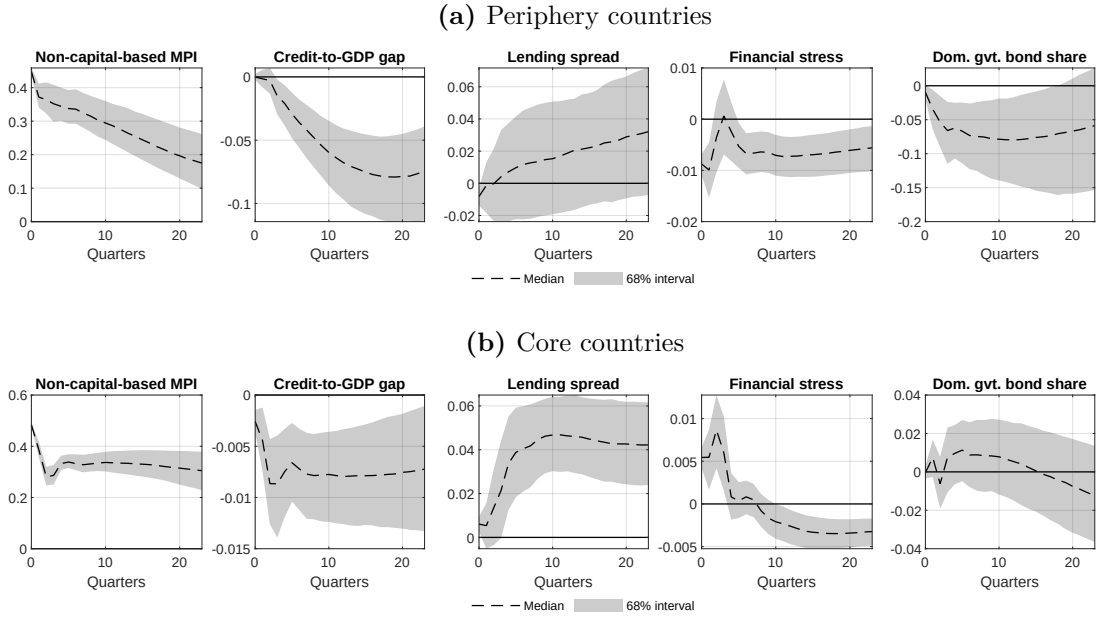
[37] In IT the CCoB was fully implemented via a single tightening step in 2014Q1.

C Non-capital-based macroprudential policy

In our baseline analysis, we focus on the effects of capital-based macroprudential policy. As discussed in Section 4.1, the main reason is the relative homogeneity of the capital-based measures contained in available policy databases, which allows for the construction of an interpretable common policy indicator. In contrast, the remaining non-capital instruments are much more diverse, rendering the construction and interpretation of a corresponding aggregate policy indicator less straightforward. Nevertheless, here we build such a macroprudential policy indicator termed MPI^{rest} and repeat our baseline estimations replacing the capital-based MPI by MPI^{rest}. The latter comprises *(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".

Figure 12 shows the country groups' impulse responses to a sudden tightening of non-capital-based macroprudential policy. We observe that the variables in both country groups exhibit a qualitatively similar reaction to the shock as reported before. In particular, we observe a drop in the credit-to-GDP gap, an increase in lending spreads and a decline in financial stress in the medium term. However, in the periphery countries the domestic government bond holdings ratio declines, while in the core countries the ratio does not respond significantly to the shock. Hence, banks' domestic government bond portfolios seem to respond differently to shocks to non-capital-based macroprudential policy.

Figure 12: Responses to non-capital-based macroprudential policy indicator



Notes: Impulse responses to a shock to non-capital-based macroprudential policy. The median impulse responses are depicted by the dashed-dotted lines. The shaded areas reflect the 16th and 84th percentiles of the posterior distribution. Responses of financial stress and in percent; of credit-to-GDP gap, domestic government bond share and lending spread in percentage points; of Non-capital-based MPI dimensionless.